SHIFTING GROUNDS:
SCIENTIFIC AND TECHNOLOGICAL CHANGE AND INTERNATIONAL REGIMES FOR THE OCEAN AND OUTER SPACE

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Abstract

Emerging planetary-scale environmental problems, such as climate change and space debris, indicate a growing need for effective governance regimes for domains beyond the borders of territorial nation-states. This dissertation addresses the basic question: what explains patterns of success and dysfunction in regimes for non-terrestrial spaces? Under what conditions can global commons regimes function to achieve their goals? The answer depends in a fundamental way on scientific knowledge and technological capability, which create, define, and describe the problems, interests, and practices that shape the formation and features of governance regimes, and thus create the conditions for their effective functioning. This project employs and extends recent revivalist geopolitical approaches examining the influences of material factors (geography, ecology, and technology), and applies them to explain important features of regimes for the ocean and orbital space. This approach claims that geography, ecology, and technology together constitute an influencing context, which creates specific problem structures and constrains possible solution sets, and thereby sets conditions for regime performance. In contrast, recent post-modernist and constructivist approaches discount the importance and influence of material contexts in shaping politics, and are incapable of explaining important aspects of regimes. Rationalist (interest-centered) approaches to theorizing regimes employ thin treatments of the material context, limiting their ability to explain regime content and effectiveness. The explanatory traction of material-contextual factors is demonstrated by a detailed examination of regime formation, content and effectiveness over four periods of ocean governance across five centuries, and orbital space over the last sixty years. These cases demonstrate that successful regime formation must foreground scientific uncertainty, ecological dynamics, and the balance of technological capability. To the extent that global commons regimes ignore the existence and dynamism of these material structures, they are more likely to fail to achieve their goals. Greater consideration of material contexts produces a strengthened International Relations theory of regimes. These findings also suggest ways to improve regime design, outlined in the concluding chapter.

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Acronyms

ABNJ	=	Areas Beyond National Jurisdiction
ASAT	=	Anti-Satellite weapon
ASW	=	Anti-submarine warfare
ATS	=	Antarctic Treaty System
AUV	=	Autonomous underwater vehicle
CHA	=	Comparative historical analysis
COPUOS	=	United Nations Committee on the Peaceful Uses of Outer Space
CPR	=	Common pool resources
DARPA	=	Defense Advance Research Projects Agency
EBM	=	Ecosystem Based Management
EEZ	=	Exclusive Economic Zone
EOS	=	Earth Orbital Space
FAO	=	United Nations Food and Agriculture Organization
G77	=	Group of 77 (developing country coalition in United Nations)
GCR	=	Global commons regime
GIUK	=	Greenland-Iceland-United Kingdom straits
GPS	=	Global positioning system
GSO	=	Geo-stationary orbit
ICBM	=	Intercontinental Ballistic Missile
IGY	=	International Geophysical Year
IMO	=	International Maritime Organization
IR	=	International Relations
ISA	=	International Seabed Authority
ITU	=	International Telecommunications Union
IUU	=	Illegal, Unregulated, Unreported fishing
IWC	=	International Whaling Commission
LEO	=	Low Earth orbit
LFA	=	Low-frequency active sonar
LTBT	=	Limited Test Ban Treaty
LTS	=	Large Technological Systems
MAD	=	Magnetic anomaly detection
MARPOL	=	Convention for the Prevention of Pollution from Ships
MEO	=	Medium Earth orbit
MPA	=	Marine Protected Area
MSY	=	Maximum Sustainable Yield
NASA	=	National Aeronautics and Space Administration
NEO	=	Near Earth object
NGO	=	Nongovernmental Organization
NIEO	=	New International Economic Order
OILPOL	=	Convention for the Prevention of Pollution of the Sea by Oil
OPEC	=	Organization of Petroleum Exporting Countries
OST	=	Outer Space Treaty
PAROS	=	Prevention of an Arms Race in Outer Space
RFMO	=	Regional Fisheries Management Organization

SOSUS	=	Sound Underwater Surveillance System
SLBM	=	Submarine-launched ballistic missile
SQUID	=	Superconducting Quantum Interference Devices
SSBN	=	Nuclear-armed strategic submarine
SSK	=	Sociology of Scientific Knowledge
STS	=	Science and technology studies
ULMS	=	Underwater Long-range Missile System
UNCLOS	=	United Nations Convention on the Law of the Sea
UNEP	=	United Nations Environment Programme
UNGA	=	United Nations General Assembly
USAF	=	United States Air Force
USN	=	United States Navy
WMD	=	Weapons of mass destruction

Planetary Geopolitics and Global Commons Regimes: A New Theoretical Agenda

"Human history becomes more and more a race between education and catastrophe."
H.G. Wells, *The Outline of History* (1920)

The dominant mode of social and political organization on the planet – the modern territorial state system – entails a form of order that does not easily translate onto the non-terrestrial domains. The construction and maintenance of borders, and the regulation of interactions across them, is extremely challenging in the vast, fluid, and relatively inaccessible spaces of the ocean, atmosphere, and orbital space. While terra firm is parceled and partitioned into distinct political units, the contemporary international institutions that govern the 'global commons' are a complicated amalgamation of jurisdictional zones, normalized practices, and poorly enforced rules and regulations. This incongruence between the dominant mode of political ordering and the majority of planetary space is significantly explained by the scientific and technological context in which the state system first emerged. In short, when the territorial state system emerged, activities in the ocean, atmosphere, and outer space were not salient in human affairs. Non-terrestrial domains were 'late breaking' relative to the land as sites of conflict and competition, and strategic, economic, and political bordering. When human activities did expand into these domains, the search for profit and advantage preceded real knowledge about the domains themselves.

Science and technology have played a central role in defining and shaping world order. The emergence of modern European states and the state system occurred in the absence of real scientific understanding about the properties, features, opportunities, and constraints of the ocean, atmosphere, and orbital space. But the globalization of human activities, first in the ocean, and then much later in the atmosphere and outer space, was enabled by technological advances that permitted the penetration and exploitation of these fluid domains beyond *terra firma*. The first non-terrestrial domain subject to modernization and globalization, starting 500 years ago, was the ocean, as explorers, traders, and imperialists took advantage of, and gave incentive to, new improvements and innovations in navigation and ship technology. The European 'global reconnaissance' also produced discoveries about the existence, contours, and resources of new terrestrial landmasses, which were deemed *terra nullius* and then incorporated into the spreading system of states. The economic growth that accompanied state consolidation was propelled in part by new technologies for the exploitation of atmospheric and oceanic resources, including industrial fishing and coal-fired power plants. Technological advancement facilitated the emergence of modern states, and was directed, invested in, and utilized by those states to productively penetrate and exploit the non-terrestrial domains. In contrast, Earth system sciences, the primary source of authoritative and coherent knowledge about these spaces, did not coalesce into coherent and professionalized academic disciplines until the 20th century. And when disciplines like oceanography, astrophysics, and aeronomy did emerge, they were often coopted, directed, or confined within the boundaries of state agencies serving the 'national interest.'

In the early and middle 20th century, an "explosion of movement" associated with technological advance changed the human relationship with non-terrestrial spaces.[1] As

[1] John A. Agnew and Luca Muscarà, *Making Political Geography*, 2. ed (Lanham: Rowman & Littlefield, 2012), 164.

the progressive development of advanced technology made these global spaces into important domains of human activity, triggered conflicts among multiple users and uses, stoked fears of over-use, and generated imperatives to formally and collectively manage spaces that began to be described and understood as 'global commons.' In addition to the emergence of what would come to be called 'common pool resources,' new 'global public goods' came into being. Global public goods, and especially common sinks, created new types and degrees of interdependence and therefore presented a unique regulatory challenge.[2] Yet the political geography constructed by the international community was anything but innovative. Although the territorial state system was developed on and for terrestrial spaces, its prevalence made partition and nationalization the default order for managing non-terrestrial global spaces. In cases where territorialization could not be readily applied, the international community was forced to develop governance arrangements that have come to be called 'regimes.'

The history of 'global commons regimes' (GCRs) can be understood as the modification of state-centric ordering principles to fit with prevailing knowledge about the nature of global spaces, their resources, and the technology that allows access to both. This adaptation to non-terrestrial spaces is often incomplete. The state-centric framework is evident in both the slow accumulation of 'customary international law,' which normalizes on-going practices, and the negotiated multilateral agreements that created the central institutions of GCRs. Unfortunately, regime building based on the imperatives and interests of states, many of which have entrenched economic and security interests in technological penetration, has generated management regimes that are often ill-suited to

[2] John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 9–11.

the realities of the Earth systems and processes of the actual non-terrestrial planetary spaces. Transnational networks, interactions, and environmental problems "openly challenge" the ability of sovereign territorial states to govern non-terrestrial spaces, and make effective international action "politically complex and conceptually confusing."[3] Despite these regimes, in the 21st century humanity finds itself in the midst of multiple and escalating ecological and geophysical crises, including massive species loss, climate change, and ocean acidification. We are now on the verge of an "earth system transformation," which will present significant challenges for politics and society.[4] The sources of and solutions to these collective action problems are significantly located within the non-terrestrial planetary domains, so repairing or replacing ineffective regimes is critical to ensure a stable, secure, and prosperous human future.

This project seeks to address a basic question: how can we better explain persistent dysfunction in regimes for non-terrestrial spaces? Under what conditions can global commons regimes function to achieve their goals? The answer depends in a fundamental way on scientific knowledge and technological capability, which create, define, and describe the problems, interests, and practices that motivate the formation of GCRs, and create the conditions for their effective functioning. When regimes are built under conditions of scientific uncertainty and rapid technological change, it is particularly difficult to design a functional institution. Scientific and technological change alters what needs to be governed and why, and how it can be governed effectively. The extension of

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[3] Agnew and Muscarà, *Making Political Geography*, 167; Scott Barrett, *Environment and Statecraft: The Strategy of Environmental Treaty-Making* (Oxford ; New York: Oxford University Press, 2003), xi; Peter M. Haas, Robert Owen Keohane, and Marc A. Levy, eds., *Institutions for the Earth: Sources of Effective International Environmental Protection* (Cambridge, Mass: MIT Press, 2001), 416.
[4] Frank Biermann, *Earth System Governance: World Poltics in the Anthropocene* (Cambride, MA: MIT Press, 2015), 7.

the territorial state system into and onto non-terrestrial domains has often proceeded without concerns about acquisition of an accurate and precise domain image: the struggle for a regime design that serves everyone's interests results in no one's interests being well-served. The impulse to extend the territorial state system – either as territorialization or nationalization – creates pathological regimes that superficially function to redress problems and satisfy interests, but are actually woefully ineffective at achieving their basic goals.

There have been some important successes in managing non-terrestrial spaces: the ozone hole is closing, acid rain is decreasing, and outer space remains nuclear weapons-free. A central argument of this project is that the pace and progress of technological advancement and scientific knowledge accumulation, and their relationship with regime design, significantly explain the successes and failures of GCRs. The variables I focus on can be described as the 'material context' because they are based on the physical environment; science reveals the contours of geography and ecology, and technology relies on physical phenomena.[5] In the last century, the state-centric orientation towards non-terrestrial domains encouraged, protected, and amplified technological penetration of the global commons, and channeled resources towards the research agendas within Earth system sciences that best served parochial state, military, and corporate interests. The material context has therefore been responded to and incorporated into GCRs in an ad hoc, half-hearted, and incomplete way. Technology has been used to justify interests in maintaining status quo uses, but generally ignored as a set of potentially empowered and mobilized enforcement capabilities. Science is repeatedly called upon to provide models,

[5] W. Brian Arthur, *The Nature of Technology: What It Is and How It Evolves* (New York: Free Press, 2009), 3.

counts, quotas and limits, but much of what scientific knowledge implies about stakeholders and negative consequences is overlooked or downplayed. Because collective problems are often extremely complex, scientific uncertainty provides an opening for politicization of scientific knowledge and authority.

Normative Motivations

Despite decades of activity, research, and theorizing, global governance has still failed to redress global environmental problems, which are worsening and growing in scale. Existing international institutions are not suited to the challenge at hand, and not ready for the challenges of the future. Negotiations and agreements over carbon emissions remain stalled, watered down, unenforced, and resisted. The ocean is being thoughtlessly polluted with industrial chemicals, fertilizers, plastics, and organic waste in ways that directly harm marine ecosystems, and will come to harm most of the human population – but only indirectly, and in the long run. The regime for outer space, built during a bipolar era to manage the security competition of two superpowers, is unprepared for commercialization of space activities, the multiplication of space actors, and the environmental problem of space debris. There are reasons to believe that the human species can effectively manage shared global spaces, and some notable success stories, but in general non-terrestrial planetary spaces are degraded, over-exploited, and under-regulated.

As a result of this situation, scholars, activists, and educators who focus on global environmental governance often have to confront feelings of helplessness, hopelessness, and despair.[6] The failures of global governance in the ocean, atmosphere, and outer space

[6] Karen T. Litfin, "Person/Planet Politics: Contemplative Pedagogies for a New Earth," in *New Earth Politics: Essays from the Anthropocene* (Cambridge, MA: MIT Press, 2016), 115–16; Michael Maniates,

often result in outcomes that can only be described as tragic. The collapse of renewable resources because of over-use has serious negative ramifications, especially for future generations and the world's poor. Changes in Earth systems processes can make existing resources unusable or downright harmful to humans. And yet, there seems to be very little learning occurring with regard to treaty making; we are largely repeating the same mistakes. The political science community is not doing enough to formulate alternatives and articulate rationales. Although a large number of International Relations (IR) scholars describe global environmental problems as a major issue for international politics, very few top scholars and publications address the topic. There is a "vast gap between perceived importance and actual work" in global environmental governance.[7] This project aims to close the gap between recognized problems and constructed solutions, by improving the tools of IR theory, and especially regime theory.

It is important to make the normative motivations animating this project explicit, because the intuitions, commitments, and values that drive any author are reflected in the structure and focus of their text. The impulse to conduct this research starts with a basic observation: the 'Anthropocene' era is marked by the permanent and costly reorganization of planetary systems, and the full extent of this transformation is dawning on the human species at a late hour. This project reinforces the urgency associated with catastrophic risks by illustrating the ways regimes are ill-suited to confront them.[8]

"Make Way For Hope: A Contrarian View," in *New Earth Politics: Essays from the Anthropocene* (Cambridge, MA: MIT Press, 2016), 135.

[7] Jessica F. Green and Thomas N. Hale, "Reversing the Marginalization of Global Environmental Politics in International Relations: An Opportunity for the Discipline," *PS: Political Science & Politics* 50, no. 02 (April 2017): 474.

[8] Sebastian Farquhar et al., "Existential Risk: Diplomacy and Governance," Global Priorities Project 2017 (University of Oxford: Future of Humanity Institute, February 2017).

There is a real risk of what Jon Mooallem refers to as "environmental generational amnesia" or shifting baselines of expectation, such that the normalization of regime failures lowers our standards for success.[9] Humans have been living with visions of catastrophic collapse for several decades, and now ecological risk has become expected and quotidian.[10] A historical approach to governance of the global commons holds regimes to their own standards of success, as articulated at the time of their negotiation. In this way, it holds the standards for effectiveness relatively constant after the regime has been formed. Regimes are best understood in their full history. Although this project shares with environmentalism a lament about the present and trepidation for the future, it looks to the past for explanations of how we got here, and how to better steer in the future.

The overall goal of this project is to provide a theoretical foundation for superior ways of thinking about shared challenges situated in non-terrestrial planetary spaces. There are several strong reasons to believe that now is the critical time to re-think the foundations and implications of GCRs. Most obviously, continued failure to successfully confront collective action problems in the global environment will be extremely damaging to human interests. But, from a strategic perspective, now is also a critical time to link theoretical arguments about political order in the global commons to the emerging forces of environmentalism.[11] Drawing the blueprints for future world order improves the chances of timely adaptation, and provides a focal point for progressives and

[9] Jon Mooallem, "Our Climate Future Is Actually Our Climate Present," *The New York Times Magazine*, April 19, 2017.
[10] Ursula K. Heise, *Sense of Place and Sense of Planet: The Environmental Imagination of the Global* (Oxford : New York: Oxford University Press, 2008), 27.
[11] Daniel Deudney and Elizabeth Mendenhall, "Green Earth: The Emergence of Planetary Civilization," in *New Earth Politics*, ed. Simon Nicholson and Sikina Jinnah (Cambridge, MA: MIT Press, 2016), 43–72.

environmentalists. Environmentalists like Stewart Brand are increasingly embracing technology as a solution to environmental problems.[12] The accelerating globalization of information and knowledge production means that society – as well as the economy – can be usefully understood globally, because knowledge and ideas can circulate much more rapidly on larger scales. Scientific consensus building is rapidly internationalizing, and collaborative data sets are increasingly commonplace.[13] Both environmentalism and globalized information systems represent fertile ground for the adoption of a new orientation towards the global commons.

Commitment to Science

This project adopts a normative commitment to the scientific method as a means for acquiring reliable knowledge about the physical world, and thus a concomitant rejection of post-modernism and strong social constructivism. A defense of this position is provided in the following chapter, because it is central to the approach of this project. Embracing a view of science as a source of useful, authoritative, and accurate knowledge enables communication with a broader and more influential audience. Embracing science also helps fill a lacuna in the literature on global environmental governance, because "we know relatively little about how scientific knowledge affects cooperation."[14] This project aims to explain how and why scientific knowledge contributes to *effective* international cooperation in non-terrestrial domains. The message throughout is that more and better science is a 'good' for humanity, which should be pursued with urgency, vigor, and

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[12] Stewart Brand, *Whole Earth Discipline: An Ecopragmatist Manifesto* (London: Atlantic Books, 2010).
[13] Joe Palca, "Why Some Scientific Collaborations Are More Beneficial Than Others," *Joe's Big Idea*, December 15, 2014; Kate O'Neill et al., "Methods and Global Environmental Governance," *Annual Review of Environment and Resources* 38, no. 1 (October 17, 2013): 456.
[14] Green and Hale, "Reversing the Marginalization of Global Environmental Politics in International Relations," 477.

expanded resources if the worst calamities of global environmental disruption and degradation are to be avoided.

Skepticism about Technology

This project adopts an orientation towards global technological systems that does not assume – as do so many – that technologies are universally and inevitably positive and benign. Technology – a complicated concept unpacked in the following chapter – entails more than a neutral and growing toolbox for human capability. It is also the *source* of complex and pernicious collective action problems. Technological advance does not automatically or reliably contribute to the collective benefit of humanity or the problem-solving capabilities of human beings. Although technology creates possibilities for effective management – especially in terms of surveillance and enforcement – it also enables more capable and available forms of access and exploitation. New employments of technology create new parochial interests in resource exploitation, and generate new problems as externalities. The design of GCRs must be attentive to two sides of the technological coin: global technological systems have both "a tendency to multiply and amplify hazards, and an ability to reduce and control them."[15]

Theoretically, this project occupies a middle ground between the Promethean techno-optimism found in works such as Buckminster Fuller's *Operating Manual for Spaceship Earth*, and the profound techno-pessimism of the 'technics-out-of-control' tradition articulated in the work of Lewis Mumford, Jacques Ellul, and Langdon Winner. These two sharply differing views range from optimistic instrumentalism to pessimistic

[15] Edward Tenner, *Why Things Bite Back: Technology and the Revenge of Unintended Consequences*, 1. Vintage Books ed (New York: Random House, 1997), 19.

determinism, and therefore make starkly different assessments of the promise and perils of technology.

On one hand, the Prometheans (such as Edward Teller, John von Neumann, and Herman Kahn) hold an optimistic view of technology and argue that the solutions to the collective problems of humanity are to be found in the expansion and acceleration of technological exploitation. The philosophical economist Robert Heilbroner describes the "Promethean spirit" behind the grand project of subjugating nature, and the ability of technology to endow humans with "literally superhuman abilities to control…nature."[16] This perspective, in which technology is a neutral and powerful tool for human use, assumes that technology is "always constructive and beneficial," even when it has negative side effects.[17] In this view, the project of controlling and managing nature for human ends is bound to succeed, because technology will provide a cornucopia of capabilities, including the ability to address any negative consequences of operating technological systems. From this perspective, technology is not the problem, and its advancement and application should be guided, but not restrained.

On the other hand, the techno-pessimists suggest that technology progressively restricts human agency. Even when humans believe that they are in control, the superhuman powers enabled by technology generate hubris and poor decision-making. Mary Shelley's *Frankenstein; or, The Modern Prometheus* is often cited as the first argument about the unintentional negative consequences of Promethean technology.[18] The idea that technology is out-of-control was also articulated by early American naturalists, who lamented the unthinking expansion and extension of technology systems.

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[16] Robert L. Heilbroner, "The Human Prospect," *The New York Review of Books*, January 24, 1974.
[17] John von Neumann, "Can We Survive Technology?," *Fortune*, 1955.
[18] Tenner, *Why Things Bite Back*, 11.

Henry David Thoreau noted in *Walden* that "we do not ride on the railroad; it rides upon us."[19] This basic insight was expanded upon in the post-World War II era, when technology was seen as a "source of genuine perplexity" and "puzzlement and disorientation" in terms of the possibilities for agency, planning, design, and control.[20] Critics like Winner and Ellul came to the conclusion that "technology in a real sense now governs its own course, speed, and destination." In this account, technology is something that confounds rather than enables the achievement of "desired and rational ends."[21] More specifically, technology is understood to create ironic unintended consequences, or "revenge effects," in addition to chronic, intractable, degenerative problems that may be global in scale. Many apparent solutions are simply the replacement of an acute problem with a chronic one; "we have resolved problems by broadening their base in space and time."[22] This deterministic and pessimistic view of technology suggests that the only beneficial course of action is comprehensive relinquishment and restraint.

This project charts a middle course between the Promethean modernists and the techno-pessimists, and between instrumentalism and determinism. It adopts a skeptical attitude to the benefits of technological advancement and the expansion of technological systems, while recognizing that new and more technology can be a critical source of solution sets. Instead of prescribing either wholesale commitment or relinquishment, this project advises that regime designers engage in systematic assessment of consequences, adopt caution in regime design, and expend resources on serious technological forecasting and assessment. In terms of determinism and instrumentalism, the project

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[19] H.D. Thoreau, *Walden, or, Life in the Woods* (London: J.M. Dent, 1908).
[20] Langdon. Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Mass.: MIT Press, 1978), 5.
[21] Ibid., 16.
[22] Tenner, *Why Things Bite Back*, 25.

entails a version of ‘soft determinism’ that sees technology (and the material context generally) as a set of boundaries, constraints, and limitations in addition to providing opportunities, possibilities, and probabilities. It guides, influences, and channels social and political behavior, but does not fully determine it. This type of structural causation is explained in more detail in the following chapter. The project especially focuses on how global technological systems shape the requirements of functionality in particular GCRs.

International Regimes

International regimes are the basic political unit of analysis in this project. The concept of a ‘regime’ emerged in political science in the late 1970s and 1980s, around the time that several domain-specific political arrangements were being supplemented by new international agreements. The regime concept is now the dominant way of thinking about institutionalized international cooperation among theorists of IR. Although there are many theories about regimes, there is no integrated regime theory.[23] Stephen Krasner’s widely cited 1983 definition describes regimes as “sets of implicit or explicit principles, norms, rules, and decision-making procedures around which actors’ expectations converge in a given area of international relations.”[24] Thus regimes can include multiple governance institutions, which focus converging expectations, establish normative frameworks, and include behavioral injunctions. Other definitions of regimes exist, such as Oran Young’s social interaction approach, which describes the evolutionary process through which patterned behavior becomes normalized and conventionalized.[25] This project speaks to all major conceptions of global regimes, but focuses on Krasner’s

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[23] Vogler, *The Global Commons*, 20.
[24] Stephen D. Krasner, ed., *International Regimes*, 11. print, Cornell Studies in Political Economy (Ithaca, NY: Cornell Univ. Press, 2004), 2.
[25] Oran Young, “International Regimes: Problems of Concept Formation,” *World Politics* 32, no. 3 (April 1980): 332.

account due to its status as a "consensus definition."[26] A preliminary version of the main hypothesis is that rules, norms, and principles of GCRs will be effective to the degree that they are informed by and tailored to prevailing and evolving conditions in the material context.

The regime concept facilitates comparative analysis and generalizations within and across cases.[27] Regimes can be distinguished based on the specific 'issue areas' they are designed to address, although issue areas fluctuate over time and have fluid boundaries.[28] This project assumes that there is an ocean governance regime and an outer space governance regime, each of which contain several distinct institutions and organizations. Regimes can be characterized by their structure and type, including integrated and centralized regimes, nested regimes, fragmented regimes, or regime complexes. Robert Keohane and David Victor argue that the type of regime that emerges depends on interests, power, uncertainty, and issue linkages.[29] This project argues that structural conditions set by the material context span and underlie each of these four sets of variables, and that therefore something more foundational is at work in the construction and implementation of functional regimes than current approaches recognize. The intuitive presence of this structure is evident when regime theorists describe what is being governed.

Regimes are often conceptually and practically tied to a domain or issue area. The notion of a 'domain' suggests a realm of activity, whereas 'issue area' is defined by

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[26] Andreas Hasenclever, Peter Mayer, and Volker Rittberger, "Interests, Power, Knowledge: The Study of International Regimes," *Mershon International Studies Review* 40, no. 2 (October 1996): 179.
[27] Vogler, *The Global Commons*, 23.
[28] Robert O. Keohane, *After Hegemony: Cooperation and Discord in the World Political Economy*, 1st Princeton classic ed, A Princeton Classic Edition (Princeton, N.J: Princeton University Press, 2005), 61.
[29] Robert O. Keohane and David G. Victor, "The Regime Complex for Climate Change," *Perspectives on Politics* 9, no. 01 (March 2011): 7–23.

conflicting uses, shared interests, or existing institutional cooperation. The definition of issue area as pre-existing areas of cooperation is analytically empty because it simply lists current treaties instead of revealing anything important about the conditions of regime formation.[30] The notions of 'domain' and 'issue area' both carry implicit – but very important – material content. If the issue area is defined by overlapping (competitive or shared) interests, these are significantly enabled and defined by technological capability, and weighed using a science-driven cost benefit analysis of short-term private and long-term common interests.[31] Political scientists frequently refer to the nature or structure of the "problem," the "resource," or the "situation" in a given area.[32] All of these conceptions refer to, or at least gesture towards, the same thing: technologically mediated access and use within the opportunities and obstacles of planetary geography and ecology. It is these material features that generate distributional patterns in terms of access, interests, and consequences of using the global commons.

This project is especially concerned with the degree and conditions of regime effectiveness, which has been a major focus of the global environmental governance literature. International regimes may be flawed, but they are also "the most developed way for nation-states to respond to transboundary environmental problems."[33] The regimes for the ocean and outer space are understood as intervening variables between the structural foundation of the material context and regime outcomes, specifically

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[30] Keohane, *After Hegemony*, 61.
[31] Radoslav S. Dimitrov, "Knowledge, Power, and Interests in Environmental Regime Formation," *International Studies Quarterly* 47, no. 1 (March 2003): 143.
[32] Barrett, *Environment and Statecraft*, xii; R. Kenneth Godwin and W. Bruce Shepard, "Forcing Squares, Triangles and Ellipses into a Circular Paradigm: The Use of the CommonsDilemma in Examining the Allocation of Common Resources," *The Western Political Quarterly* 32, no. 3 (September 1979): 277; Oran Young, "Land Use, Environmental Change, and Sustainable Development: The Role of Institutional Diagnostics," *International Journal of the Commons* 1, no. 5 (2011): 82.
[33] Rolf Lidskog and Göran Sundqvist, "The Role of Science in Environmental Regimes: The Case of LRTAP," *European Journal of International Relations* 8, no. 1 (2002): 79.

whether or not regimes achieve their goals. This new approach foregrounding the structural-material conditions for governance is needed, because the nature and features of global environmental problems are increasingly salient to the search for international solutions. This approach can be understood as a revival of earlier approaches to global commons regimes. The importance of technology for creating conditions of interdependence was explicitly recognized by John Ruggie's 1975 article that is credited with introducing the concept of a regime, and was incorporated into early reviews of existing global commons regimes.[34] Unfortunately, this early appreciation of the importance of technology has been increasingly lost, along with a concomitant de-emphasis on science. Although Krasner's 1982 review article lists "knowledge" as one of the five types of regime theories, this strand has been mostly limited to the epistemic communities literature that "[explains] outcomes not with science but with scientists," and has been largely appropriated by constructivist theorists, who largely discount or ignore the influence of the material context.[35]

Case Selection

This dissertation will utilize case studies of two global commons regimes: the ocean and outer space. A planned expanded version of the project will also incorporate the atmosphere case, but other places generally described as 'global commons' will be excluded. Antarctica is a frequently cited case, but it is not suited to this analysis for two reasons. First, fundamentally, Antarctica is 'terra firma' and the other global commons are not. Although the Antarctic is structurally a 'global' commons, insofar as it is intimately connected to global ocean and climate systems, it is politically an

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[34] John Gerard Ruggie, "International Responses to Technology: Concepts and Trends," *International Organization* 29, no. 3 (Summer 1975): 557–83.
[35] Dimitrov, "Knowledge, Power, and Interests in Environmental Regime Formation," 127.

‘international’ commons because its treaty system includes a very limited set of members (a ‘club’). This means that its management challenges are different – transaction costs are lower and domestic politics (like Chilean and Argentinian nationalism) have a larger influence. There are also multiple territorial claims on the frozen continent, which the Antarctic Treaty System only puts in abeyance. Second, Antarctica is an easy case for the influence of science and technology. The Antarctic Treaty System is explicitly based on science: its formation followed a collective scientific research endeavor during the International Geophysical Year, full participation in the regime requires active scientific research, and its evolution over time has been widely explained with primary reference to new environmental and ecological knowledge.[36]

In contrast, the ocean, atmosphere, and outer space are ‘global’ (or more accurately, ‘planetary’) in both their material contours and their collective management. Although specific physical features characterize each domain, the success and failure of their regimes have been almost entirely explained with reference to the changing power, interests, and ideologies of negotiating parties, regime members, and domain users. These cases share important similarities, which makes the effect of their material contextual features easier to discern. Clusters of international institutions, which were developed and implemented over time, constitute each domain-specific regime. All of them are usefully analyzed starting in the 1950s, and each regime negotiated its major central institutions in the 1960s and 1970s. In each case, lawyers and diplomats initially attempted the straightforward extension of territorial models of ownership and control, which had to be modified or rejected to fit the non-terrestrial circumstances. They were also all subject to the ideological ferment of the ‘New International Economic Order’ movement and the

[36] Vogler, *The Global Commons*.

‘Group of 77’ coalition, which is reflected in the common theme of ‘technology transfer’ as a regime mandate, and ‘equity’ as a regime principle. These historical similarities make commons regimes well suited for cross-domain comparison because their material and technological foundations exhibit substantial variation, while the power, interest, and idea-based influences exhibit similarities of the Cold War period.

Table 1 - Ocean and Outer Space Cases

	Ocean	Outer Space
Geophysics	74% of planet surface Circulation at multiple scales Expansive depth, extreme pressure Atmospheric exchange	Planetary extent Gravity Orbital pathways, orbital decay Cosmic radiation
Ecology	Plentiful and diverse	None
Earth Sciences	Oceanography Geophysics Marine Sciences	Astronomy Geodesy Astronautics
Primary activities	Renewable resource extraction Spatial extension resources Sink resources Non-renewable energies Scientific research	Satellite-based observation Satellite-based communication Satellite-based navigation Weapons transit Scientific research
Potential activities	Renewable energies Non-renewable resource extraction	Weapons basing Renewable energies Non-renewable resource extraction Asteroid diversion
Institutions/ Organizations	UNCLOS International Seabed Authority UNEP Regional Seas Seabed Arms Control Treaty London Convention (1972) MARPOL 1973/78 IMCO/IMO (1958, 1982) ICRW/IWC (1946, 1982) ITLOS	OST + Protocols/Conventions Bogota Declaration (1976) Moon Treaty (1979) ITU COPUOS UNOOSA
Scope of Regime	All ocean activities All ocean areas (minimal in ABNJ)	'Space objects' Highly permissive
Nature of Regime	Central institution Several organizations Mixed adjudication	Central institution U.N. organizations No specific adjudication

The Geopolitical School

In the colloquial sense, 'geopolitics' has come to be used as a synonym for inter-state rivalry and competition, especially in the realm of security. But there is a larger and more theoretical tradition of geopolitics that analyzes the influence of the material context on human affairs, and especially international politics. The idea that the natural environment shapes human political institutions – both their formation and outcomes – is very old.[37] This project sits squarely within the geopolitical school of IR, which can be described as either nascent or renascent in the existing literature on regimes, depending on one's historical perspective. Geopolitical theory attempts to discern relationships between the material world of geography and technology, and the social world of politics. In particular, geopolitical theory explains the dependent variables of order/disorder, cooperation/competition, and peace/conflict with reference to spatial and environmental aspects of the material context. As a school of thought, geopolitics has origins in early naturalist arguments about the relationship between climate and topography on one hand, and human identity and political forms on the other. Aristotle, Montesquieu, and Bodin all made such arguments, connecting natural laws and limits to human capacity, will, and behavior, as well as the emergence of particular political forms.[38]

In addition to their rigid and strong determinism, these early naturalist theories have been widely criticized for their inability to account for technological change. The industrial revolution prompted the inclusion of technology as a primary variable in geopolitical thinking about international politics, in addition to the geographical and topographical features highlighted in earlier iterations of naturalism and materialism. In adding technology as a primary variable, naturalism was recast as 'historical materialism.'[39] Liberal internationalists like John Dewey and H.G. Wells focused on the political and social implications of the "ubiquitous notion of technologically produced

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[37] Daniel Deudney, "Bringing Nature Back In: Geopolitical Theory from the Greeks to the Global Era," in *Contested Grounds: Security and Conflict in the New Environmental Politics*, ed. Daniel. Deudney and Richard Matthew (SUNY Press, 1999), 26.
[38] Clarence J. Glacken, *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*, 7. (Berkeley, Calif.: Univ. of Calif. Press, 1996); Daniel Deudney, "Geopolitics as Theory: Historical Security Materialism," *European Journal of International Relations* 6, no. 1 (2000): 77–107; Ladis K.D. Kristof, "The Origins and Evolution of Geopolitics," *The Journal of Conflict Resolution* 4, no. 1 (March 1960): 15–51.
[39] Daniel Deudney, *Bounding Power: Republican Security Theory from the Polis to the Global Village* (Princeton: Princeton University Press, 2007), 195–97.

interdependence."[40] In general, however, the adoption of technology as a "master variable" in geopolitical thought was somewhat uneven during the early 20th century.[41]

Partially as a result of adding technology to the core set of material-contextual variables, the early twentieth century school of 'global geopolitics' was less deterministic than earlier naturalistic theories.[42] Ideas about the material context directing (or directly causing) social and political outcomes were replaced with a broader, and more structural notion of causation: the material context (geography and technology) creates and entails constraints, limitations, and influences on international politics.[43] According to Ladis Kristof, three schools of geopolitical thought – the American, Anglo-Saxon, and German – focused on the relationships between world politics, global geography, and the technological systems of the industrial revolution (communication, destruction, and transportation). American and Anglo scholars – especially Alfred Thayer Mahan, Halford Mackinder, and Nicholas Spykman – evaluated the security-viability of particular political forms in the larger political system, and provided diplomatic, strategic, and military advice to their respective Western hegemons.[44] These geopolitical thinkers focused on the state as the primary unit of international politics, and sought to explain the influence of geography and technology on interstate interaction. The American school of global geopolitics generally argued that the changing material context necessitates new and different political forms for achieving welfare and security. Within geopolitics as a type of historical security materialism, Anglo-American theorists analyzed not just the

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[40] Ibid., 205.

[41] Harold Sprout, "Geopolitical Hypotheses in Technological Perspective," *World Politics* 15, no. 2 (January 1963): 187–212.

[42] Geoffrey Parker, *Western Geopolitical Thought in the Twentieth Century* (New York: St. Martin's Pr, 1985), 174.

[43] Kristof, "The Origins and Evolution of Geopolitics."

[44] Daniel Deudney, "Geopolitics and Change," in *New Thinking in International Relations*, ed. Michael W. Doyle and G. John Ikenberry (Boulder: Westview, 1997), 98.

role of states and empires, but also various republican unit types and interstate federations and union.[45]

Another important advance and refinement of geopolitical theorizing in recent decades is found in work by Harold and Margaret Sprout, who begin *The Ecological Perspective on Human Affairs* (1965) with a recognition that international political theory relies on ideas about the material context, "variously designated the situation, setting, stage, arena, environment, or milieu," yet theories still employ environmental variables "loosely and imprecisely."[46] The Sprouts explicitly adopt an 'ecological perspective,' and seek to describe and explain how a variety of environmental factors affect what humans choose to do ("undertakings") and how those plans turn out ("outcomes"). They introduce a distinction between the 'milieu' and the 'psycho-milieu,' with the former being "the whole spectrum of environing factors; human as well as nonhuman, intangible as well as tangible" and the latter the image or idea of the milieu maintained by individual humans.[47] Both the milieu and the psycho-milieu affect behavior and outcomes. The Sprouts forward theories of environmental possibilism and probabilism. In possibilist doctrine, the milieu does not compel or direct human behavior, but provides a set of opportunities and limitations for it.[48] The milieu affects "operational results" of various undertakings, whether or not particular actors are aware of the effect.[49] In contrast, probabilism is a model of behavior that considers the influence of the psycho-milieu on "psychological states (values, preferences, moods, attitudes, perception,

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[45] Deudney, *Bounding Power*.
[46] Margaret Sprout and Harold Sprout, *The Ecological Perspective on Human Affairs* (Princeton, N.J.: Princeton University Press, 1965), 6.
[47] Ibid., 27.
[48] Ibid., 83.
[49] Ibid., 95.

cognition, recognition) and actions (choices, decisions, undertakings)."[50] This second focus on psychological phenomena is a major difference between this project and the Sprouts' ecological perspective; I do not wade into the realm of psychology and individual decision-making. However, there are several important similarities. I also focus on ecology, in addition to geography and technology. The Sprouts' description of their possibilism thesis is a paradigmatic example of structural causation; they conceive environmental factors as a "matrix, or encompassing channel…which limits the execution of undertakings" regardless of perceptual or psychological factors.[51] Finally, *The Ecological Perspective on Human Affairs* and this project both ultimately prescribe the systematic collection of "a very wide range of precise and up-to-date information" about the material context, as a key condition of "successful international statecraft."[52]

In recent years, the theoretical presence of geopolitics in IR theory has been associated with the work of Daniel Deudney. His refurbishment and theoretical development of ideas found in a nascent or implicit form in earlier geopolitics has provided framework and theoretical propositions that bring geopolitical theorizing into the contemporary planetary era.

In addition to reviving the geopolitical school in IR, Deudney also recasts its history in his 2008 book *Bounding Power*. *Bounding Power* reframes the intellectual history of materialist geopolitics to reveal a marginalized, but originally very innovative and consequential, IR tradition that places the main claims of Liberalism and Realism as fragments of a larger, more complete, but more inchoate 'republican security theory.' 'Republican security theory' concerns "the relations among security-from-violence,

[50] Ibid., 99–100.
[51] Ibid., 11.
[52] Ibid., 1.

material contexts, and types of government."[53] This historical project demonstrates that the political agenda of global governance to moderate and exit interstate anarchy is not an idealist or utopian enterprise, but is rather the necessary next step in adjusting political arrangements to the imperatives of a material context marked by planetary-scale violence interdependence at intense levels. This historical exegesis demonstrates that early naturalist, global geopolitical thinking and contemporary international institution building to replace anarchy, are all intelligible as responses to security imperatives created by shifting scales of intense violence interdependence. Deudney argues that contemporary political theory is characterized by a "gross under appreciation or misappreciation of the importance of material-contextual factors, of nature, geography, ecology, and technology."[54] Although he does mention the importance of ecology, Deudney's argument about security-viable political forms focuses on geography and technology, and he frames materialist geopolitics as "an argument about *material contexts composed of geography and technology as restraining and empowering forces.* [emphasis original]"[55]

This project is, in important ways, inspired by and consistent with the grand historical political theorizing contained in *Bounding Power*. It draws upon the history of material-contextual arguments surveyed and unpacked by Deudney, and seeks to contribute to the revival of materialist geopolitical thinking. It employs a 'limitations and opportunities' view of structural causation, similar to Deudney's focus on restraints and empowerments. However, this project differs from Deudney's argument in its emphasis on global commons regimes, ecology, and collective action problems arising in efforts to govern fluid non-terrestrial planetary spaces. It also differs in that it is not primarily

[53] Deudney, *Bounding Power*, 3.
[54] Ibid., xii.
[55] Ibid., 16.

focused on security from violence, but instead analyzes ecological and economic aspects of the interplay between material context and international regimes.

This project's effort to develop a materialist geopolitical theory of regimes for non-terrestrial spaces employs the overall framework of geopolitics. It is part of an emerging body of theory that can be understood as "neoclassical geopolitics," which attempts to make more theoretically explicit what was nascent and underdeveloped in earlier geopolitical theories.[56] The geopolitical legacy connects with the present project primarily through the argument that changing material conditions influence the form and character of functional institutions. It differs with many geopolitical theories, however, in replacing the state with the regime as the primary political and institutional unit of interest.

Planetary Geopolitics

The approach taken here is part of an emerging body of neo-geopolitical theory best described as 'planetary geopolitics.' Deudney first coined this term in his 1983 monograph, *Whole Earth Security: A Geopolitics of Peace*. Deudney was primarily concerned about the conditions of international security given the existence of planetary-scale weapons. He notes that states attempting to achieve national security have focused on developing the "ability to garrison the planet's commons," and that military competition now takes place in the "vast, fluid and otherwise uninhabited realms of water, air, ice, and space."[57] Deudney's central point, which he describes as the "lesson of planetary geopolitics," is that security has now become indivisible, and therefore can

[56] Deudney, "Geopolitics and Change," 100.
[57] Daniel Deudney, *Whole Earth Security: A Geopolitics of Peace* (Washington, D.C., USA: Worldwatch Institute, 1983), 19, 54.

only be achieved cooperatively.[58] Although his focus in *Whole Earth Security* is on the requirements of international security, Deudney's more general point applies to the project at hand. He suggests that the fate of the ocean, atmosphere, and outer space is of "life or death concern for all peoples."[59] While in 1983 Deudney confined this conclusion to the issue of security from nuclear weapons, the sentiment rings true for the contemporary magnitude of environmental problems in non-terrestrial domains. And in later works, Deudney states the value of a planetary geopolitics approach more generally, as a theoretical response to the "planetary-scale material and social reality" created by globalization.[60] Planetary geopolitics, as described by Deudney, can therefore be understood as a more general "contextual-material geographic understanding of the contemporary global situation."[61] Its central theme is the importance of planetary-scale material context for achieving desired outcomes in international politics.

Geopolitics is an imperfect term for the insights that it is here being employed to represent, because it emphasizes the 'geo-' but also encompasses the 'techno-' and 'eco-' aspects of the material context. The addition of 'planetary' aims to capture and emphasize the latter features, because it calls to mind the technological and ecological interconnections and interdependencies that weave the planet together into a single dynamic entity. By foregrounding the material features of planetary processes, ecosystem structures, and global technological systems, this theory identifies unique influences, limitations, and opportunities in planetary-scale non-terrestrial domains. The basic

[58] Ibid., 40.
[59] Ibid., 10.
[60] Daniel Deudney, Theory Talk #60: Daniel Deudney on Mixed Ontology, Planetary Geopolitics, and Republican Greenpeace, interview by P. Schouten, November 20, 2013, 1, 17.
[61] Daniel Deudney, "All Together Now: From Cosmopolitan Space to Terrapolitan Place," in *Institutional Cosmopolitanism*, ed. Thomas Pogge and Luis Cabrera (Oxford University Press, Forthcoming), 33.

assumptions of planetary geopolitics, and how it is applied to the study of global commons regimes, will be surveyed and supported in detail in the following chapter. But to establish the need for an additional treatment, this type of theory can be usefully compared and contrasted with two existing studies of global commons regimes. John Vogler and Frank Biermann take tentative steps towards an environment-centered regime theory, but stop short of claiming a new type of approach, or linkages with geopolitical theory.

Vogler has several major publications on the topic of global commons regimes, in which he explains both their content and effectiveness. Vogler describes the 'global commons' as a social construct, an idea that emerged in the late 1980s as a result of "shifts in human knowledge, capability and perceptions of scarcity" and overuse.[62] Although Vogler does not refer to the milieu and psycho-milieu, or the material context, his variables of interest fall squarely within the geopolitical tradition. Vogler is primarily concerned with scientific knowledge and technological capability, and how they shape and portray an issue area or domain. In terms of regime effectiveness, Vogler focuses on the importance of adaptiveness and flexibility of institutions. In particular, he argues that global commons regimes must adopt the function of generating and incorporating new knowledge about the domain at hand.[63] Judging whether a regime design needs to adapt in order to be effective requires the establishment of "independent reference points, reflective of whatever scientific consensus may exist."[64] Because issue areas change over time, and often have fluid boundaries, institutional inertia and inflexibility is a major

[62] John Vogler, "Global Commons Revisited," *Global Policy* 3, no. 1 (February 2012): 61, 63.
[63] Vogler, *The Global Commons*, 160.
[64] Ibid., 155.

cause of ineffectiveness.[65] For Vogler, institutional effectiveness is significantly determined by how regimes account for “the complexity, difficulty and extent of the problem” as it exists in the real world.[66]

This project shares much with Vogler’s account of global commons regimes, in terms of explicanda and explicans. But it both updates and surpasses Vogler’s account of the relationship between global commons regimes and the material context of non-terrestrial domains. First, Vogler treats “shared scientific understandings” as a regime principle (‘beliefs of fact and causation’), which implies automatic regime change in light of new information.[67] In contrast, I treat scientific understandings of non-terrestrial places as an exogenous variable, which may or may not be incorporated into regimes and prompt regime change. Second, Vogler argues that treating the “mismatch between the scope of a regime and the dimensions of the underlying problem, perceived ecologically” as a source of ineffectiveness is impractical.[68] He argues that effectiveness does not require that the scale of the solution match the scale of the problem.[69] In contrast, I suggest that mismatch between the scope and scale of the issue area and the regime is an importance source of ineffectiveness, and one that must be remedied. Finally, whereas Vogler is optimistic that regimes have been getting more effective “with respect to curbing environmentally damaging behavior,” the cases examined in this project suggest the opposite – things are getting worse, and existing regimes are likely to fail to achieve their objectives.[70]

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[65] John Vogler, “Regimes and the Global Commons: Space, Atmosphere, and Oceans,” *Global Politics: Globalization and the Nation-State*, 1992, 125; Vogler, *The Global Commons*, 185.
[66] Vogler, *The Global Commons*, 177.
[67] Ibid., 30.
[68] Ibid., 179.
[69] Ibid., 222.
[70] Ibid., 185.

A more recent treatment of international regimes for the environment comes from Frank Biermann's *Earth System Governance*. The *Earth System Governance* project is both a single book, and a "large multinational project" instigated by Biermann himself, and bringing together hundreds of researchers.[71] The book and project represent a "clear and standard reference point" for projects like this one, because of the depth and breadth of Biermann's treatment of global governance.[72] Biermann defines Earth system governance broadly, to include "the sum of the formal and informal rule systems and actor networks at all levels of human society that are set up to steer societies toward preventing, mitigating, and adapting to environmental change and earth system transformation."[73] He is concerned with the governance "architecture," which is the "overall institutional arrangement within an issue area" and therefore encompasses issue-specific regimes.[74] Unlike Vogler, Biermann is motivated by a concern for the "prevailing lack of effectiveness" evident in existing governance architectures designed to confront global environmental problems.[75] Although his explanation for ineffectiveness is complex, Biermann notes that "there remains a serious mismatch between the research and recommendations of earth system analysts and the actions of political decision makers."[76] This project centers the mismatch between scientific advice and institutional design, and argues that a 'match' is appropriately understood as a condition of regime effectiveness. In this way, it adds to Biermann's list of five features of effective governance architecture. Another similarity is Biermann's overall aim: *Earth*

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[71] John S. Dryzek, "Earth System Governance: World Politics in the Anthropocene. By Frank Biermann. Cambridge, MA: MIT Press, 2014. 260p.," *Perspectives on Politics* 14, no. 01 (March 2016): 176.
[72] Ibid., 178.
[73] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 9.
[74] Ibid., 82.
[75] Ibid., 10.
[76] Ibid., 9.

System Governance is analytical, in that it seeks to explain ineffectiveness, but also normative in its critique of existing governance systems.

Like the regime analysis offered by Vogler and Biermann, a planetary geopolitics approach highlights the role of science and technology in the creation of effective and functional regimes. These concepts will be defined and explored in detail in the next chapter, but their theoretical import is discussed below.

Global Technology

Global technological systems are firmly in the background of human political affairs, resulting in a kind of technological somnambulism, where we "willingly sleepwalk through the process of reconstituting the conditions of human existence."[77] This project centers the features and evolution of global technological systems, as a shaper of practices, creator of interests and problems, and opportunity for particular solution sets. More specifically, technological systems facilitate new types, quantities, and distributions of access and exploitation, but also new possibilities for verification and enforcement. In chapter two, technology is precisely defined, and the geopolitical approach to technology is contrasted with Science and Technology Studies, which entails a more constructivist, and less materialist, theoretical orientation. The geopolitical approach to technology has four basic features. First, it takes the composition and distribution of technology as key variables that change over time. Although the 'level' or 'degree' of technological advancement is often discussed in a colloquial way, these types of descriptions only make sense with reference to the past, and tend to embed a teleological assumption. Composition and distribution offer a relatively neutral way to

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[77] Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology*, Nachdr. (Chicago: Univ. of Chicago Press, 2001).

grasp qualitative technological change. Second, geopolitical theory recognizes that technology is not an inert set of tools for human users, but is in a real sense in ‘control’ of driving activity and consequences in non-terrestrial spaces. This middle ground between instrumentalism and determinism was described above. Third, because global technological systems often represent both the primary source of problems and an opportunity for various solution sets, they are central to the question of effectiveness. Both Promethean moderns like Fuller and eco-pragmatists like Brand identify technological systems as a central opportunity to control and change our collective fate.

The fourth feature of the geopolitical treatment of technology connects the theory with a larger body of work on political institutions. Geopolitical theory highlights the spatial features of stakeholder groups, such that formal membership is secondary to the group created by the scale and scope of consequences. The empirical changes associated with the industrial revolution helped prompt the notion that technological systems create increasingly extensive interdependence, and therefore ever-larger stakeholder groups. In *The Public and Its Problems* (1927), John Dewey discussed the requirements this situation created for effective political forms. Dewey argued that technological change was a “permanent revolution” that required flexibility and adjustment. As the material context changed, so did the “public” – or the group with interactions and spillovers that are lasting and significant.[78] The communications and transportation technologies of the industrial revolution created a public much larger than in the past.

The key question became how to revise and reform government so it could maintain its positive functions without becoming a hierarchy. Dewey favored an

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[78] John Dewey, *The Public and Its Problems an Essay in Political Inquiry* (University Park, Pa.: Pennsylvania State University Press, 2012).

administrative state capable of task accomplishment and regulatory interventions of a type that formerly occurred at lower levels of government. Dewey saw democracy as a necessary element of maintaining functionality, a kind of experimentalism that can/should constantly evaluate the nature and scope of "publics" to produce "communities" (self-aware publics). A major contrast between *The Public and Its Problems* and this project is the scale of government/governance considered. The main thrust of Dewey's argument was that levels of interdependence and interaction previously only experienced at the local level were now being experienced at the scale of continental-size nation-states. As Deudney points out, the increase in scale is a function of geography and technology; "material contexts will determine the scope of publics."[79] In the contemporary period, a central guiding assumption of materialist geopolitics is that high levels of interaction and unintended consequence – and thus publics – now exist at the planetary scale. The geopolitical approach draws on the notion of publics and communities – publics are groups of common fate, and communities are self-aware publics. But "not all publics give rise to communities," and many publics created by interactions in the ocean and outer space remain unrecognized, unacknowledged, and/or unaccounted for by regimes.[80]

Earth System Science

Earth system science has an important role in planetary geopolitics, because it defines the domain and issues to be managed, through increasingly precise and accurate maps and causal models. In the language of the Sprouts, Earth system science represents

[79] Daniel Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities," in *The Greening of Sovereignty in World Politics*, ed. Karen T. Litfin (Cambridge, Mass: The MIT Press, 1998), 310.
[80] Deudney, *Bounding Power*, 209.

an important source of information and ideas in the construction of the psycho-milieu. The assumptions associated with scientific knowledge production are unpacked in the next chapter, but its theoretical role in planetary geopolitics is briefly reviewed here. Existing accounts of the impact of regime design on effectiveness stress endogenous institutional variables like decision-making procedures, membership, access to the resource, and formal compliance.[81] But the scientific enterprise offers a standard of comparison for regime design, a source of guidance and information that is often overlooked or under-emphasized. Scientists discover and characterize ecological systems, and trace and define geographic dimensions like location, distance, and distribution. The mental maps and models they produce represent an understanding of the natural world that is indispensable – and profoundly influential – for policy making.

As described above, this project makes a normative claim about the benefits and virtues of scientific knowledge production. Governance challenges in the global commons are best understood through the lens of Earth system science, instead of the alternative and hegemonic national-state-territorial perspective. While the former seeks a maximally informed and increasingly precise image of non-terrestrial domains, the latter distorts and cherry-picks information for its own (often misperceived) benefit. The state-centric perspective is highly durable, because the state was and is the primary locus of interest formation in negotiations over the shared use of the global commons. In 1975, regimes were understood to be "transition systems" from the territorial state system to a kind of global governance architecture. [82] But far from being the beginning of a

[81] Thomas Bernauer, "The Effect of International Environmental Institutions: How We Might Learn More," *International Organization* 49, no. 2 (Spring 1995): 351–77.
[82] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 877–92.

movement away from the state, regimes actually re-inscribed the political geography of the state system. The political geography of global commons regimes is primarily international, which is to say dominated and defined by state-to-state relationships. Earth system science, in contrast, produces geographical information that is planetary in scale and scope, including complex and dynamic processes that create non-territorial communities of mutual interest and shared vulnerability. In this way, it generates an essentially non-state-centric map of the domain and issues to be managed. This alternative image plays a theoretical role by offering a standard of comparison and evaluation for existing regimes.

State-centric approaches to management of the global commons have been largely ineffective; states have historically subsidized and protected technological exploitation of the commons, primarily funding scientific research that justified or enhanced use activities. This combination of funding technological access and willfully ignoring scientific understanding results in over-exploitation of the global commons, and poor understanding of the negative consequences of doing so. For example, state-supported oceanography during the Cold War was dominated by geophysical research – to the detriment of ecological research – in order to pursue security-imperatives related to submarine technology.[83] Economic-imperatives similarly disincentivized ecological research. The state and the fishing industry were more interested in catching fish than counting them. As a result, the 'industrial revolution of the sea' was unaccompanied by a thorough account or real understanding of the contours and limits of marine

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[83] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005).

ecosystems.[84] The global character of the marine ecosphere was treated as irrelevant to the formation and satisfaction of state-based interests. Even ostensibly global orientations like the 'common heritage' concept were actually about equalizing states' rights to access resources. What has been missing is a focus on truly global shared resources, such as renewable food sources, clean air, uncluttered orbits, and ecosystem services. The engine of knowledge production about shared global resources and interests – Earth system sciences – has been truncated, coopted, and misdirected by the imperatives of modern states. This willful ignorance is an important source of regime ineffectiveness.

Conclusion

This project introduces a geopolitical theory of global commons regimes that supplements and complements existing explanations of their ineffectiveness. This involves making a coherent and salient critique that is overlooked by the existing literature, as well as adumbrating several conditions of regime effectiveness in non-terrestrial domains. Planetary geopolitics identifies structural constraints and opportunities for regime functioning, which are unique to the non-terrestrial domain at hand. There are multiple 'structures' examined in this project: the structure of material reality, the structure of scientific knowledge accumulation, and the structure of technological change. Unlike many conventional structural theories, planetary geopolitics can (and does) admit that regimes shape outcomes and behavior, and are not mere epiphenomena.[85] This project aspires to schematize the impact on regimes that is

[84] Hance D Smith, "The Industrialisation of the World Ocean," *Ocean & Coastal Management* 43, no. 1 (January 2000): 11–28.
[85] Stephen D. Krasner, "Structural Causes and Regime Consequences: Regimes as Intervening Variables," *International Organization* 36, no. 2 (Spring 1982): 194.

expected in the context of different types of scientific and technological change, modified by the particular features of non-terrestrial domains.

Analytically, the dependent variables of this project are patterns of practice, formation of interests, and definition of problems. These represent what state and non-state actors actually do in the global commons, and what state negotiators want out of regimes. Practices, interests, and problems are not fully determinative of regime effectiveness, but they have important relationships with most standards of effectiveness. Change in practices can indicate whether regimes need to modify, and have modified, actor behavior. Change in interests can indicate how and whether regimes serve or satisfy national and international interests. Change in problem definition represents shifting requirements for regime effectiveness. It is posited, and assumed, that GCRs are ineffective, and this project seeks to better explain why.

Normatively, this project attempts to throw off the blinders of the state system, and focus instead on the interaction between technological, geophysical, and ecological systems on a planetary scale. A macro-scale materialist history of global commons regimes situates these institutions between the unfolding and amplification of technologies of observation and access, and the geophysical and ecological 'resources' that drive humans into the non-terrestrial realms. Although the primary contribution of my argument is a geopolitical theory that complements existing regime theories, it also encompasses several implicit and explicit critiques of existing governance institutions. The basic prescription to international diplomats hoping to achieve collective goals and avoid shared vulnerabilities is this: pay closer attention to the patterns of change in science and technology, because they have important implications for opportunities, obstacles, problems, and solutions in global commons domains. There is urgency to the theory building undertaken here, because technological change is accelerating, the human population is growing, and policymakers continue to disregard and deny scientific consensus on environmental issues. The planetary geopolitics perspective contains insights for effective treaty design, and contributes to the construction of a ‘planetary consciousness’ that may help overcome the domestic political obstacles to new multilateral agreements. These ideas are considered in the conclusion.

Philosophical Foundations: Scientific Epistemology, Mixed Ontology

This project pushes against recent trends in International Relations (IR) scholarship, and seeks to revive a theoretical approach that has been largely set aside by IR scholars. The study of global commons regimes undertaken here is incompatible with, and unintelligible to, post-modernism, critical theory, strong social constructivism, and interpretivist political theory. This chapter explains the divergence between planetary geopolitics and these bodies of theory at the level of philosophical foundations. More specifically, it unpacks and defends the commitment to a partial materialist ontology and scientific epistemology, or the idea that there is exists an objective material world, which scientists can describe and explain with special authority. This chapter describes geopolitical theory in broad outlines, setting the stage for a more specific description of planetary geopolitics, as applied to global commons regimes, in the following chapter.

The first section will clarify the theoretical contribution made by this project, which can be described as a geopolitical theory of global commons regimes (GCRs). The second section surveys on-going debates about the status, role, and function of science. I argue that scientific knowledge production is a communal activity that produces inter-subjective beliefs with increasing congruence to an objective material reality. The third section defines and describes the importance of technology to the overall project, and characterizes two different types of technological change. The conclusion introduces the connections between the philosophical foundations of the project, and the approach taken to analyze GCRs in the case chapters.

Geopolitical Theory

This project aims to generate a more sophisticated theory of global commons regimes (GCRs) by applying a strand of largely neglected materialist arguments in classical geopolitical theory. Reformulations of 'old materialism' have already proven fruitful in the security realm, and in this project I hope to extend geopolitical theory to the analysis of collective action problems, and attempts to deal with them, in the Earth's non-terrestrial realms.[86] Geopolitical theory has virtually disappeared as a distinct theoretical position in IR, so its absence from theories of global commons regimes is unsurprising. Those who do call for a re-emergence of geopolitics often focus on the security side, including issues like resource scarcity and environmental security.[87] But environmental problems in non-terrestrial spaces are also a fruitful avenue for employing the insights of geopolitical theory. In this section, I describe what a geopolitical theory entails. In subsequent sections, I examine what a geopolitical theory assumes about the world, and argue that it provides distinct benefits as a theory of global commons regimes.

Geopolitical theories focus on the features of the material context of human activity – specifically geography, ecology, and technology – as determinants of the basic opportunities and constraints for actors and activity in international politics. Geopolitical analysis implies a structural theory of change, insofar as change in the material context channels or influences the type of activities undertaken in the global commons.[88]

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[86] Daniel Deudney, "Geopolitics and Change," in *New Thinking in International Relations*, ed. Michael W. Doyle and G. John Ikenberry (Boulder: Westview, 1997); Daniel Deudney, "Geopolitics as Theory: Historical Security Materialism," *European Journal of International Relations* 6, no. 1 (2000): 77–107.; Daniel Deudney, *Bounding Power: Republican Security Theory from the Polis to the Global Village* (Princeton: Princeton University Press, 2007).

[87] John A. Agnew and Luca Muscarà, *Making Political Geography*, 2. ed (Lanham: Rowman & Littlefield, 2012), 185.

[88] A structure is a "relatively permanent pattern of relationships between the elements of a system," a definition which comes from: John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 186.

A contribution of this argument to the larger project of resurrecting and reformulating geopolitical theory is its treatment of Earth system science. The material context as revealed by science is typically treated as an assumed pre-condition for political action, but this project engages it as a real set of variables. ‘Geography’ and ‘ecology’ constitute much of the material context, in that they refer to the actual material reality of non-terrestrial domains, but they also represent *ideas about* the material context. This distinction employs the Sprouts’ concepts of ‘milieu’ and ‘psycho-milieu.’ A geopolitical theory of GCRs therefore operates on two levels – it considers how the material context structures human activity, and how scientific knowledge about the material context shapes ideas about interests and problems. When technology, geography, and ecology change in the real world, so do the possibilities for human activity. For example, new hull technology makes deep-sea submersion possible, the melting Arctic ice cap makes new transportation routes possible, and the extinction of a fish species makes fishing it impossible. Such activities are what GCRs seek to manage. Earth system science stimulates the development of new technologies, but its main contribution to geopolitical theory is the way that scientific knowledge accumulation changes *ideas about* geography, ecology, and technology. Earth system science informs the content of interests and reveals the structure of environmental problems. It reveals when existing technologies have harmful side effects, when non-terrestrial ecologies are fragile, and when geographies are more or less permanent. These ideas fill out important concepts like ‘shared vulnerability’ and ‘sustainable use,’ and may either support or undermine existing political authorities. In other words, Earth system science, through its characterization of the features of geography and ecology, and the consequences of technology, helps set the agenda for GCRs. Whether or not scientific information is used to shape the formation of regimes is an important determinant of their effectiveness.

This kind of materialist geopolitical theory provides approaches to global environmental governance that confront three basic challenges: moving targets, complexity, and incomplete information.[89] It also unpacks these concepts and addresses a significant part of their effect on regimes. 'Targets' for governance often move because of new technologies, or new insights about the geographical distribution of consequences. 'Complexity' is a feature of the geography and ecology of non-terrestrial realms, whose multiple interacting and overlapping processes are difficult to disaggregate and/or partition. Incomplete information is slowly reduced by the efforts of Earth system scientists, who collect data, generate explanations, and disseminate important information about activities and consequences in the global commons (important examples include the International Geophysical Year and World Ocean Census). The geopolitical theory of GCRs cannot account for the full range of target movements, problem complexities, and gaps in information, but it does analyze them as important features of change driven by material-contextual variables.

The geopolitical theory developed here adds important insights to the analysis of GCRs, but it is not capable of standing alone. The material context affects GCR outcomes by shaping the conditions of possibility for access and exploitation, but geopolitical variables also matter because of their influence on intervening variables like power, interests, and ideas. In this way, geopolitical theory *complements* existing theories of GCRs by highlighting the way that new insights about the natural world (science) and

[89] Kate O'Neill et al., "Methods and Global Environmental Governance," *Annual Review of Environment and Resources* 38, no. 1 (October 17, 2013): 442

new possibilities for use-activities (technology) influence non-material variables. The relationship between a geopolitical theory and existing theories of GCRs will be examined in the following chapter, but first the basic commitments and distinct advantages of geopolitical theory will be reviewed. The next section examines the ontological and epistemological assumptions of the project.

Modern Natural Science

Geopolitical theory offers several advantages compared to regime theories that emphasize power, interests, and ideas. Geopolitics is a "meta- or master framework that, without predetermining policy choice, suggests long-term factors and trends" in international politics.[90] Understanding how changes in material contexts affect regime formation and effectiveness over time is underpinned by a more general understanding of scientific realism. This section will unpack the notion that science and technology undergo change conditioned by the features of material reality. Materialist geopolitical theory's commitment to a philosophy of scientific realism and a soft version of technological determinism distinguishes it from some existing approaches to the study of international politics. Science and technology directly impact the formation of interests and understanding of problems that motivate regime building. Breaking down the meaning of science and technology for governance in non-terrestrial spaces is therefore an important component of geopolitical theory building.

The basic ontological and epistemological commitments of geopolitical theory differ in major ways with strong social constructivist and post-modernist approaches. The philosophy of 'scientific realism' is the conceptual foundation of geopolitics, and it

[90] Colin S. Gray, *The Geopolitics of the Nuclear Era: Heartland, Rimlands, and the Technological Revolution*, Strategy Paper 30 (New York: Crane, Russak & Comp, 1977), 11.

distinguishes this theory from several other social science approaches. This section will survey opposing theoretical approaches to international politics, and unpack the partial materialist ontology and scientific epistemology that characterizes geopolitics. Geopolitical theory rests upon a mixed ontological foundation: the independent variable of interest is the material context, but the dependent variable is regimes, which are social and political constructions. A key assumption is that the scientific method and scientific community represent a privileged and relatively authoritative form of knowledge production. The geopolitical approach assumes a basic relationship between the objective features of the material context and the ideas about that material context produced by Earth system scientists. This commitment is also compatible with pragmatist conceptual foundations, but there are advantages to scientific realism which will be surveyed at the end of this section.

The 'Science Wars'

Materialist geopolitics is positioned on one side of a "perennial philosophical dispute" between forms of philosophical realism and anti-realism.[91] In the mid-1990s, renewed tensions between proponents of scientific realism and their antagonists in social constructionism and post-modernism boiled over into the so-called 'science wars.'[92] Both ontology and epistemology were once again theaters of heated philosophical dispute. Anti-realists argued that the world is socially constructed, and targeted the special epistemic status of scientific knowledge. Scientific realists defended their belief in an objective material world, authoritatively described and understood by science. They

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[91] Anjan Chakravartty, "Scientific Realism," ed. Edward N. Zalta, *The Stanford Encyclopedia of Philosophy*, Winter 2016.
[92] Timothy D. Lyons, "Scientific Realism," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al., Oxford Handbooks (New York, NY: Oxford University Press, 2016), 643.

suggested that this view was commonsense in the modern world.[93] This debate about epistemology – what knowledge the scientific method can produce – is important because of its implications for the reliability of science as a guide to practical action. These issues are addressed by the philosophy of science, which seeks to "disentangle the part of scientific theories that is up to us and the part that is up to the world."[94] The scientific image of the world is used to define global environmental and collective action problems, so its trustworthiness is a matter of paramount political concern.

Sociology of Scientific Knowledge

The most recent iteration of the debate about the status of scientific knowledge started with a historical perspective on the development of science. Thomas Kuhn's landmark 1969 book *The Structure of Scientific Revolutions* described change in scientific knowledge as occurring through episodic "paradigm shifts" instead of incremental data accumulation.[95] Each paradigm shift creates a "revolutionary divide" between the old "normal science" and the new "normal science," which are "incommensurable" with one another. These shifts subvert or undermine the idea of linear and incremental scientific progress, because the new "normal science" is not understood as "epistemically superior" to the previous.[96] For Kuhn, the impossibility of neutral observation meant that sociological factors played an important role in driving shifts in scientific concept and theory. Scientific paradigms are therefore socially determined, and "create the reality of scientific phenomena" instead of describing

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[93] John R. Searle, *The Construction of Social Reality* (New York: Free Press, 1995), 150.
[94] Stathis Psillos, "Having Science in View: General Philosophy of Science and Its Significance," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al. (New York, NY: Oxford University Press, 2016), 143.
[95] Thomas S. Kuhn and Ian Hacking, *The Structure of Scientific Revolutions*, Fourth edition (Chicago ; London: The University of Chicago Press, 2012).
[96] Chakravartty, "Scientific Realism," 4.2.

features of a world independent of minds.[97] Other scholars quickly expanded the idea that scientific consensus was driven by social factors instead of better observations and explanations of the natural material world. Kuhn's book has been described as "the single most important influence on the development of social constructivism," but the author himself later questioned the constructivist understanding of science.[98] By that time, however, even more radical and elaborately developed versions of social constructivism had emerged.

Scientific realism contrasts with and opposes the 'Sociology of Scientific Knowledge' (SSK) program developed by members of the 'Edinburgh school,' which includes work by Barry Barnes, David Bloor, Randall Collins, Steven Shapin, Simon Schaffer, Karin Knorr Cetina, and Bruno Latour, among others. The SSK program was an outgrowth of anti-naturalism from the 1950s and 1960s, which "refused to take science as an authority on epistemic matters."[99] A core commitment of the SSK approach, described by Bloor, is "symmetry in explanation," the idea that beliefs that are 'false' and beliefs understood to be 'true' are epistemically equivalent.[100] Bloor argues that the success of scientific knowledge must be explained just as much as the success of any other idea.

This argument against scientific authority includes a rejection of materialist ontology. A central assumption of SSK is that scientific knowledge is "not constrained by nature," but socially constructed. SSK scholars insist that "intellectual content is always

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[97] Ibid.

[98] Stephen Cole, "Voodoo Sociology: Recent Developments in the Sociology of Science," in *The Flight from Science and Reason*, ed. Paul R. Gross, N. Levitt, and Martin W. Lewis, Annals of the New York Academy of Sciences, v. 775 (New York N.Y: The New York Academy of Sciences, 1996), 275–76.; Lyons, "Scientific Realism," 642.

[99] Francesco Guala, "Philosophy of the Social Sciences: Naturalism and Anti-Naturalism in the Philosophy of Social Science," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al. (New York, NY: Oxford University Press, 2016), 45.

[100] Lyons, "Scientific Realism," 641.

and altogether amenable to sociological explanation."[101] Construction of a particular concept may result from social interactions within the scientific community, or from the pressure of broad social and economic interests that determine the "content of scientific ideas."[102] Because they believe the injection of social norms and interests is inevitable, SSK scholars often propose an alternative 'democratic epistemology,' which dilutes the bias of a particular standpoint by explicitly injecting a diversity of gender, class, race, or other marginalized perspectives.[103] In short, they 'doubled down' on the social determination of scientific knowledge.

A particularly influential voice in SSK and Science and Technology Studies (STS) is actually an anthropologist, Bruno Latour. In *Laboratory Life* (with Steve Wooldgar, 1979), *Science in Action* (1987), and *We Have Never Been Modern* (1993), Latour lays out a social constructivist view of science. For Latour, a scientific fact, concept, or theory achieves consensus by being "propagated" as a "network of standardized practices" that is "extended and stabilized."[104] Although he ultimately agrees with Shapin and Schaffer that "the facts are fabricated," Latour offers a corrective to the overly-sociological Edinburgh school.[105] He argues that facts must be crafted and called into existence, because the material world does not describe itself, but that they are

[101] Peter Dear and Sheila Jasanoff, "Dismantling Boundaries in Science and Technology Studies," *Isis* 101, no. 4 (December 2010): 766.
[102] Cole, "Voodoo Sociology: Recent Developments in the Sociology of Science," 275.Susan Haack, "Towards a Sober Sociology of Science," in *The Flight from Science and Reason*, ed. Paul R. Gross, N. Levitt, and Martin W. Lewis, Annals of the New York Academy of Sciences, v. 775 (New York N.Y: The New York Academy of Sciences, 1996), 263.
[103] Haack, "Towards a Sober Sociology of Science," 262.
[104] Bruno Latour, *We Have Never Been Modern*, 3. print. (Cambridge, Mass: Harvard Univ. Press, 1994), 24.
[105] Ibid., 25.

not purely socially constructed, “not made out of thin air, not of social relations, not of human categories.”[106] For Latour, facts have a dual nature.

Instead of understanding the world as purely social or purely material, Latour introduces the idea of “hybrids,” which are “mixtures of nature and culture.”[107] He argues that an ontology that separates the objective/natural from the subjective/social takes an “epistemological wrong turn.”[108] As the “official dogma of modernity,” the objective/subjective and natural/social distinction infects both scientific realism *and* the SSK literature. Scientific realism seeks to provide objective material explanations of scientific facts, whereas SSK pursues “purely social explanations.”[109] Both positions reify the modern dualist ontology, and therefore both are subject to Latour’s critique. For Latour, nothing is purely social or purely material, and everything is exactly both. But while Latour’s position can be understood as part of the SSK literature more broadly, he is explicitly opposed to scientific realism. Indeed, one of Latour’s basic goals is to strip the natural sciences of their authority and legitimacy as sources of knowledge.[110]

The idea of hybrids is, however, too obscure and vague to have utility for the present project. Latour’s hybrids are understood to be part nature and part culture, but he provides no guidance for gauging, understanding, or wrestling with different proportions between the two. Hybrids appear as “consistently balanced entities” that are half material,

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106 Ibid.
107 Ibid., 30.
108 Oscar Kenshur, “The Allure of the Hybrid: Bruno Latour and the Search for a New Grand Theory,” in *The Flight from Science and Reason*, ed. Paul R. Gross, N. Levitt, and Martin W. Lewis, Annals of the New York Academy of Sciences, v. 775 (New York N.Y: The New York Academy of Sciences, 1996), 289.
109 Ibid., 292.
110 Cole, “Voodoo Sociology: Recent Developments in the Sociology of Science,” 277.

half social, and therefore always require the same type of explanation.[111] This hybrid ontology creates epistemological difficulties; Latour cannot fully explain "why certain objects become stabilized and others do not."[112] In contrast to Latour's ontology, which suggests that every thing in the world is material and social, the mixed ontology of geopolitical theory accepts that while reality is a mixture of material and social, some things are almost entirely material, while other things are almost entirely social. And even in the case of hybrids, the social or material aspect of an object or fact may be more interesting, illuminating, or explanatory.[113] Under this view, a scientific fact or theory is stabilized as consensus over time because of its congruence with material reality. A socially entrenched position can be unseated by a "mass of evidence" acquired through scientific activity, because that evidence is indicative of some feature of material reality.[114] This allows historians and philosophers of science to explain why some scientific views stabilize while others are unsettled.

Science and Technology Studies

Another body of scholarship inspired by Kuhn, and also in sharp contrast with geopolitical theory, is Science and Technology Studies (STS). This body of theory is guided by three propositions: scientific knowledge is determined by the social and political context, its value is negotiated socially, and it is "co-produced" with political order.[115] STS especially focuses on the role of science in shaping regimes under conditions of scientific uncertainty, but does not problematize decision making in the

[111] Kenshur, "The Allure of the Hybrid: Bruno Latour and the Search for a New Grand Theory," 295; Latour, *We Have Never Been Modern*, 144.
[112] Cole, "Voodoo Sociology: Recent Developments in the Sociology of Science," 283.
[113] Kenshur, "The Allure of the Hybrid: Bruno Latour and the Search for a New Grand Theory," 295.
[114] Lyons, "Scientific Realism," 243.
[115] Kate O'Neill, *The Environment and International Relations*, Themes in International Relations (Cambridge, UK ; New York: Cambridge University Press, 2009), 97.

absence of scientific consensus. STS scholars understand science as "intertwined" with policy, and argue that science is important exactly because it is "messy, impure, and political."[116] As a result, the STS view embraces the politicization of science, rejecting the ideas that scientific practice should be separate from politics, and that scientific consensus should precede policy formation. Scientific knowledge and social interests "adapt to one another in a process of mutual development," instead of science providing authoritative information for politics and society.[117] Rolf Lidskog and Göran Sundqvist describe the process of "stage management," through which science is "strategically presented" as an authoritative knowledge source.[118] They argue that scientific knowledge succeeds when it resonates with "settled forms of public knowledge-making," including "shared normative and cultural understandings of the world."[119] Scientific consensus, therefore, has no special status, and is best understood as a compromise between social actors. Scientific credibility is earned by "the persuasive power of the individuals and institutions that speak for science, rather than the strength of internal consensus.[120]

This project offers a direct contrast to STS prescriptions for governance. I argue that decision-making under uncertainty is likely to lead to the creation of ineffective regimes, especially when uncertainty is overlooked or willfully ignored. Science also produces more useful information for regime architects when it is less politicized, by being relatively isolated from political pressures. Good science is therefore not a result of democratic inclusion of all viewpoints, but comes from the rigorous application of the

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[116] Rolf Lidskog and Göran Sundqvist, "When Does Science Matter? International Relations Meets Science and Technology Studies," *Global Environmental Politics* 15, no. 1 (February 2015): 6, 1.
[117] Ibid., 6.
[118] Ibid., 8.
[119] Ibid., 13–14.
[120] Ibid., 10.

scientific method. These points will be addressed and supported in the following chapters.

Social Constructivism

The mixed ontology and scientific epistemology of this project also contrasts with social constructivism as an approach to studying politics (its specific application to global governance will be considered in the following chapter). Whereas scientific realism believes that the world is found (by science), social constructivists believe that the world is made through social relations (including within the scientific community). Because constructivists are committed to the idea that all or most of reality is socially constructed, they focus on the explanatory power of ideas, norms, and identities. In regards to scientific knowledge, they argue that the substantive content of any consensus theory or concept is a poor indictor of its significance or influence.[121] This is because the scientific "norm of disinterestedness" is a fantasy, and scientists subconsciously build theories that reflect and reinforce interests and power in society.[122] Because the process of observing is already laden with theoretical expectations and projections, it cannot be understood as a neutral form of evidence. Social constructivists therefore focus on the specific external ideas that shape observation and theory building, such as individualism, anthropocentricism, and neo-liberalism.

While some strong forms of social constructivism reject the existence or relevance of an observer-independent material world, many are at least compatible with a mixed material/social ontology. And arguably social constructivism requires a material world; "A socially constructed reality presupposes a reality independent of all social

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[121] O'Neill, *The Environment and International Relations*, 97.
[122] John Ziman, *Real Science: What It Is, and What It Means*, (Cambridge: Cambridge University, 2002), 235.

constructions, because there has to be something for the construction to be constructed out of."[123] But in general, the strong form of social constructivism rejects the idea that scientific theories "can be understood as furnishing knowledge of a mind-independent world."[124] A middle position understands scientific knowledge as "both found and made," a combination of construction and discovery (which varies depending on the subject).[125] Social factors may determine the choice, professional reward, and funding of particular research.[126] But material reality has a "refractory nature," such that it tends to shape the results of observation and measurement.[127] Even if social scientific activity drives the formation of a consensus, the material context inevitably shapes the content of that consensus.

Science Defined

The meaning and coherence of 'science' has been the subject of debate for several centuries, and especially the last several decades. Early modern scientists such as Galileo Galilei and Isaac Newton followed a basic method: "conduct experiments to test your hypothesis and allocate your confidence in proportion to the strength of your evidence."[128] But the details, practices, and standards of the scientific method have been the subject of contrasting and evolving opinions. Most observers have concluded that "science is too diverse, too protean, to be captured in full by a definition."[129] When definitions are provided, they are broad and general. Astronomer Neil deGrasse Tyson defines the scientific method as: "Do whatever it takes to avoid fooling yourself into

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[123] Searle, *The Construction of Social Reality*, 190.
[124] Chakravartty, "Scientific Realism."
[125] Ziman, *Real Science*, 235–36.
[126] Chakravartty, "Scientific Realism."
[127] Ziman, *Real Science*, 318.
[128] Neil deGrasse Tyson, "What Science Is and How and Why It Works," *Skeptical Inquirer*, October 2016.
[129] Ziman, *Real Science*, 12.

thinking something is true that is not, or that something is not true that is."[130]Although science "does not have an essence waiting to be discovered," this should not be taken as an invalidation of the concept.[131]

While there are many local variations on the scientific endeavor, a "global model of science" exists that attaches social authority to particular categories, standards, and outputs.[132] 'Science' is understood here as a systematic research and theorizing activity that involves the accumulation and interpretation of information about the material world. It is a special mode of knowledge production, which generates an image of the natural world through disciplined and professionalized inquiry and analysis. It offers representations and explanations of phenomena, and often constructs experiments to isolate particular causal relationships.[133] Employing theories, hypotheses, and principles, scientists attempt to progressively uncover causal connections and mechanisms, and laws of nature.[134] The goal of science is to produce coherent and broadly accepted inter-subjective understandings, among scientists, of "how and why things are as they are."[135]

Although a single definition of 'science' is elusive, the various scientific disciplines share a common object of study: nature itself.[136] Scientific epistemology – the idea that the scientific method can reveal truths about the natural world – is based on the philosophy of external realism, also called 'scientific realism.' Scientific realism entails an ontological commitment to a world that exists independent of human minds, which is

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[130] Tyson, "What Science Is and How and Why It Works."
[131] Psillos, "Having Science in View: General Philosophy of Science and Its Significance," 141.
[132] Gili S. Drori et al., eds., *Science in the Modern World Polity: Institutionalization and Globalization* (Stanford, Calif: Stanford Univ. Press, 2003).
[133] Psillos, "Having Science in View: General Philosophy of Science and Its Significance," 143.
[134] Ibid., 147.
[135] Eugene B Skolnikoff, *The Elusive Transformation Science, Technology, and the Evolution of International Politics* (Princeton, N.J.: Princeton University Press, 1994), 14
[136] Psillos, "Having Science in View: General Philosophy of Science and Its Significance," 158.

patterned by general and fundamental principles and has a "hidden-to-the-senses causal-explanatory structure."[137] The background assumption that an objective material world exists contains no particular content, because its "details and properties" are "precisely the kind of issue scientific research aims to elucidate."[138] In terms of epistemology, scientific realism understands scientific theories and concepts as descriptions of that world, which constitute knowledge. Scientific statements are 'true' to the degree that they are accurate descriptions of the objective material world. Although scientists can produce mistaken or flawed conclusions, scientific realism adopts a "positive epistemic attitude towards the content of our best theories and models, recommending belief in…aspects of the world described by the sciences."[139] This orientation is embedded in the paradigms, norms, and culture of academic science.[140] Scientific realism combines beliefs about the world with an understanding of scientific practice; "science discovers objective truths."[141]

Scientific realists generally ignore the "global skeptical challenge" represented by strong versions of SSK and post-modernism.[142] Although they recognize that science is a social institution, and that scientific practices have sociological aspects, scientific realists argue that these features do not necessarily undermine the process of rational inquiry.[143] Scientific realism has two basic defenses against strong social constructivism. First, the existence of an objective material world leaves room for social construction of knowledge, but guarantees that *all* knowledge is not socially constructed. The belief that

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[137] Drori et al., *Science in the Modern World Polity*, 9.; Searle, *The Construction of Social Reality*, 153.; Psillos, "Having Science in View: General Philosophy of Science and Its Significance," 148.
[138] Otavio Bueno, "Epistemology and Philosophy of Science," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al., Oxford Handbooks (New York, NY: Oxford University Press, 2016), 237.
[139] Chakravartty, "Scientific Realism."
[140] Ziman, *Real Science*, 319.
[141] Tyson, "What Science Is and How and Why It Works."
[142] Bueno, "Epistemology and Philosophy of Science," 237.
[143] Haack, "Towards a Sober Sociology of Science," 259.

the world contains “brute facts” and therefore “reality is not logically constituted by representations” is fundamentally compatible with the idea of social construction.[144] Social constructions exist and matter, but in science, they are constrained and influenced by the natural material world.[145] The existence of brute material facts explains why scientific theories ‘work’ despite social, cultural, and political difference and changes, and why the existence of scientific objects is often corroborated by multiple modes of detection and measurement.[146] Second, scientific realists argue that scientific norms for accepting a knowledge claim minimize the influence of sociological influences. Insofar as warrant and evidence are the standards for acceptance of a scientific theory, the room for social explanations is minimized.[147] In sum, scientific epistemology is designed to minimize the risk that scientific theories merely reflect social, political, and economic interests and ideas.

Although philosophers of science disagree about the precise methods for generating scientific knowledge – such as falsification, verification, or anomaly testing – scientific realists agree that the general methods of structured observation and repeated experimentation produce a special form of knowledge. Bracketing the debate among scientists about methods, the general term ‘scientific epistemology’ describes all such ways of coming to know and understand the world. Scientific knowledge has a special, authoritative status because of the norms and practices associated with scientific methods of inquiry and analysis.

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[144] Searle, *The Construction of Social Reality*, 27, 156.
[145] Cole, “Voodoo Sociology: Recent Developments in the Sociology of Science,” 284.
[146] Chakravartty, “Scientific Realism.”
[147] Haack, “Towards a Sober Sociology of Science,” 260.

The production of scientific knowledge is a communal endeavor; observations and theories are not considered scientific 'facts' until they have been vetted by repeated and transparent research activity, including several forms of peer review. The process by which a scientific finding becomes scientific consensus is an important feature of scientific knowledge production, because it explains how an inter-subjective belief comes to be understood as an objective fact; 'consensus-building' connects scientific epistemology to its realist ontology. "The demand for justification renders science an inter-subjective enterprise; the demand for external grounding renders it an objective enterprise."[148] Scientific norms of communalism, universality, disinterestedness, originality, and organized skepticism produce an "agonistic arena" where "the particular bias of each individual is neutralized in the collective outcome."[149] This arena is social, but designed to bracket social influences. For example, the competition for personal scientific prestige increases the rigor of peer review. The desire to 'make a name' for oneself encourages the collection of new data, or creative fashioning of new experiments. The "intellectual virtues" that guide scientific knowledge production are embedded in the institutions and norms of the scientific community, as opposed to relying on the virtue of individual scientists.[150]

Despite concerns about the integrity of scientists and the reliability of scientific findings, actual data fraud, or lying about procedures, is exceedingly rare, and tends to

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[148] Psillos, "Having Science in View: General Philosophy of Science and Its Significance," 145.
[149] Ziman, *Real Science*, 159.
[150] Noretta Koertge, "Wrestling with the Social Constructor," in *The Flight from Science and Reason*, ed. Paul R. Gross, N. Levitt, and Martin W. Lewis, Annals of the New York Academy of Sciences, v. 775 (New York N.Y: The New York Academy of Sciences, 1996), 272.

cluster in the biomedical sciences.[151] Scientific knowledge is "self-correcting" in that falsehoods "will eventually be discovered and rejected."[152] The key to this progressive aspect is the close connection between warrants and acceptance – without a sufficient quality and quantity of evidence, a scientific dictum will not be considered true or close-to-true.[153] A large, dynamic, and de-centralized scientific community questions whether the given evidence provides sufficient warrant for accepting a scientific explanation. The process of inquiry and analysis involves cooperation and competition across borders and generations.[154] When a scientific finding persists in stable form through the gamut of peer review, repeated testing, and new data collection it becomes a "practical, working consensus" upon which scientists base new theories and techniques.[155] In other words, scientific consensus is a provisional declaration of congruence between objective material reality and the inter-subjective understandings of scientists. The stability of a scientific object or theory in the community can therefore be taken as a "reasonable indicator of its objectivity."[156]

A common counter-argument to these claims about the value of scientific epistemology is that states and other powerful actors control scientific knowledge accumulation in a way that biases its outcomes. While it is certainly true that interested and powerful actors support and restrict scientific activity, it is not the case that such actors control the direction of scientific consensus, especially in the medium-to-long term. An illustrative example is British and American attempts to justify the dumping of

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[151] David Goodstein, "Conduct and Misconduct in Science," in *The Flight from Science and Reason*, ed. Paul R. Gross, N. Levitt, and Martin W. Lewis, Annals of the New York Academy of Sciences, v. 775 (New York N.Y: The New York Academy of Sciences, 1996), 31–38. 31.
[152] Ibid., 31.
[153] Haack, "Towards a Sober Sociology of Science," 261.
[154] Ibid.
[155] Ziman, *Real Science*, 256.
[156] Ibid., 6.

nuclear waste in the ocean. At first, 'health physicists' sanctioned nuclear dumping as safe for humans, exactly as their government sponsors wanted. But quelling public fears required the involvement of oceanographers, because of their special knowledge of diffusion and uptake in the marine environment. The oceanographers – with funding from the American and British governments – came to different conclusions about the safety of dumping nuclear waste in the ocean. In short, government sponsorship did not influence the ultimate and durable scientific consensus.[157] Examples abound of situations where governments wanted one thing, and scientists found another.

The Nature of Scientific Progress

Scientific knowledge production occurs in two phases. The observational phase collects data for the purpose of exploring and mapping natural systems. The explanatory phase involves theory development, through practices of experimentation and hypothesis testing, and processes of analysis and interpretation. Arguably there is a third phase, which entails the creation of dynamic models. The first phase discovers, the second phase explains, and the third phase predicts. This section will focus on the first two phases, unpacking their components with a focus on the role and limitations of social construction. In short, the room for politicized interpretation grows as a scientific idea moves from phase one through phase three.

The main activities in the observation phase are measurement, documentation, and mapping, in order to progressively characterize material phenomena by refining and adding detail to scientific maps. This phase is especially important in Earth system sciences because humans have limited direct access to the vast reaches of non-terrestrial

[157] Jacob Darwin Hamblin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, N.J.: Rutgers University Press, 2008).

planetary domains. We could tell very little about outer space by just looking up, and about the ocean by looking out from the shore. The observational phase is often taken for granted when we think of 'science,' but it is critical for defining what exists in the domain of investigation.[158] The philosopher of science Otavio Bueno provides a useful account of the relationship between observation, instrumentation, and scientific knowledge (as understood by the scientific realists). Although pre-existing concepts influence how we understand the world, "it is not up to us what we will observe when we open our eyes."[159] SSK theorists sometimes argue that the use of instruments like telescopes, microscopes, and submersibles embeds theory into observation, such that what we see will be determined by how we are looking and what we are looking for. But instruments are "relatively theory-neutral" because only a few basic theories are needed to identify and process observational data.[160] Bueno argues that when working correctly, modern instrumentation provides "strong epistemic access" and generates "robust data," which can be used to evaluate scientific theories.[161] Empirically, observational practices and the majority of observational data do not change when scientific theories or paradigms change, even when paradigms are incommensurable.[162] The results of scientific observation therefore "provide stable, theory-neutral grounds for theory assessment."[163]

Only when physical patterns have been accurately mapped can scientists begin the second phase of investigation, using hypothesis testing and experimentation to theorize

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[158] Stephen S Hall, *Mapping the next Millennium: The Discovery of New Geographies* (New York: Random House, 1992).
[159] Bueno, "Epistemology and Philosophy of Science," 244.
[160] Ibid., 245–46.
[161] Ibid., 247.
[162] Ibid., 244.
[163] Ibid., 245.

about the origins and causal mechanisms of natural systems. In this phase, politics and personality are a more substantial influence because of the central role of interpretation and extrapolation, which creates room for external ideas and ideologies. This second phase involves the articulation of new theories and the erosion of old ones. A distinction can be made between core knowledge, which is widely accepted as true, and the "research frontier," where new knowledge is being produced and there is a lack of consensus among scientists.[164] Although interpretation on the research frontier is more open to social, cultural, and political influences, continued data collection, hypothesis testing, and peer-review eventually invalidate or delegitimize interpretations which do not comport with material reality. In sum, scientific progress moves towards more accurate and less political understandings over time.

The basic distinction between the observation and theory-building phases of scientific knowledge production is not essentially sociological, because the former is a logical pre-requisite to the latter. A scientist cannot make an argument about 'why' until the 'what,' 'where,' and 'how' are sufficiently established. This does not imply that the two phases of scientific investigation are entirely sequential – new observational data can bolster or undermine existing theories that were built on more limited data sets. In other words, both phases can and do occur simultaneously, but the theory-building phase relies upon the products of the observational phase.[165]

This distinction between phases explains why linear scientific progress can occur despite political, cultural, and sociological influences. Many aspects of science – such as its disciplinary organization, its immediate purposes, and its standards of evidence – are

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164 Cole, "Voodoo Sociology: Recent Developments in the Sociology of Science," 284.
165 Shelby D. Hunt, "A Realist Theory of Empirical Testing: 'Resolving the Theory-Ladenness/Objectivity Debate,'" *Philosophy of the Social Sciences* 24, no. 2 (June 1994).

subject to these influences. But what science discovers through observation is not socially constructed; even sensing apparatuses that are directed towards particular purposes can only discover what is actually there. In other words, "science is a genuine amalgam of 'construction' and 'discovery'…it marries intention with contingency."[166] The part of science that includes the progressive uncovering of the features of the material world, and unraveling of its structures and processes, explains the existence of scientific progress in a social world.

Although scientists recognize that the objective physical world is never *fully* accessible, the goal of science is to produce inter-subjective understandings with maximal congruence to it. This is the basic relationship posited between the material context and ideas about it; over time, scientific theories change in a way that converges on the truth.[167] The shared commitment to the existence of an objective material world explains why both non-linear shifts in theory and concept, as described by Kuhn, and linear accretions of data and knowledge can occur. The notion of advancement has a long history in the scientific community; Francis Bacon first proposed the ideal of scientific progress as a collective goal for scientists.[168] Isaac Newton captured the notion of a collectively constructed edifice of knowledge that persists throughout generations in his famous statement: "If I have seen further, it is by standing on the shoulders of giants." The notion of progress does not imply that all scientists have a shared goal, although practical problem solving has been a consistent driver of scientific activity.[169] Progress also does not imply the accretion of exact truth; while data and observations accumulate

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[166] Ziman, *Real Science*, 36.
[167] Chakravartty, "Scientific Realism."
[168] Alexander Bird, "Scientific Progress," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al. (New York: Oxford University Press, 2016), 544.
[169] Ziman, *Real Science*, 14.

in a linear way, interpretation is a more hectic and variable process of convergence. The "moving frontier" of pre-consensus research can "land all over the place until experiments converge in one direction or another."[170] Scientific theories often progress by coming closer to the truth, even if they do not always reach it.[171]

More than just an ideal, scientific progress and knowledge accumulation is evident in world history. The phenomenon of 'multiple independent discovery' lends support to the idea that observational data reflects the existence of objective material phenomena, as opposed to being specific to a particular social and political context.[172] The phenomenon of accidental scientific discoveries also indicates that the purposes of scientific investigation are separable from the knowledge it produces.[173] Scientific knowledge, in general and over time, has moved in a particular direction – congruence with objective material reality.

An historical example illustrates how the accumulation of scientific knowledge relates to the distinction between the observational and interpretive phases of scientific investigation. Humans used to believe the ocean floor was smooth, but observational data revealed the mid-Atlantic ridge. Enough observations produced an inter-subjective consensus about the crevasses, seamounts, and slopes at the bottom of the sea. This scientific knowledge about how the ocean floor is shaped *could* be undermined by new and contrary observational data, but we do not expect to find such data because the inter-subjective consensus is understood to have a basic congruence with objective material

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[170] Neil deGrasse Tyson, "What Science Is -- and How and Why It Works," *The Huffington Post*, November 18, 2015.
[171] Bird, "Scientific Progress," 561.
[172] David Lamb and Susan M. Easton, *Multiple Discovery: The Pattern of Scientific Progress* (Avebury, Buckinghamshire: Avebury, 1984).
[173] Royston M. Roberts, *Serendipity: Accidental Discoveries in Science*, (New York: Wiley, 1989).

reality. Even the strongest social, political, or cultural influences could not re-construct the ocean floor. In contrast, theories about *why* the ocean floor has a variegated topography are subject to interpretation, and indeed Soviet and American scientists offered competing explanations. Disputes about the causes of lithosphere textures were significantly conditioned by Cold War rivalry, the organization of professional disciplines, and standards of evidence.[174] The eventual non-linear shift from Soviet-origin platform tectonic theory to plate tectonics occurred in response to linear accumulations of data that recommended one theory over another. Today, plate tectonics is taught to children as established scientific fact.

The special knowledge of non-terrestrial domains produced by the consensus of Earth system scientists has increasingly approximated the features of the actual material context. Sometimes vested interests challenge scientific findings in political arenas and media outlets, but over time the conclusions of the scientific community tend to win out.[175] The overall success of scientific theories developed over several centuries suggests that current scientific understandings of the ocean and outer space are "substantially trustworthy."[176] But it is likely that much remains to be known about the chemical, biological, ecological, geographical, and geophysical features of non-terrestrial domains. Uncertainty persists in particular areas, including patterns of cause and consequence in global environmental problems. Specific areas of uncertainty will be reviewed in the case chapters. The achievement of reasonable certainty and consensus is inevitable, but the

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[174] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005), 214–15.

[175] Naomi Oreskes, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, 1st U.S. ed (New York: Bloomsbury Press, 2010).; Edward J Larson, *Evolution: The Remarkable History of a Scientific Theory* (New York: Modern Library, 2006).

[176] Hunt, "A Realist Theory of Empirical Testing: 'Resolving the Theory-Ladenness/Objectivity Debate,'" 152.

rate at which it emerges is substantially a result of society and politics. Today, the primary obstacle to progress in scientific knowledge about planetary systems is funding for research posts and projects.[177]

Pragmatism

Because this project is based upon the ontology and epistemology of scientific realism, it is also fundamentally compatible with American pragmatist philosophy. The existence of scientific consensus is an empirical question, but the meaning of its content is an epistemological one. Scientific knowledge accumulation can be understood as progress towards a full picture of the objective material world, or advancement in the efficacy or utility of science for achieving human goals and purposes. The former view is scientific realism, and the latter is a type of pragmatism. For pragmatists, something is 'true' when it 'works' or is useful for satisfying human needs and desires.[178] This practical epistemology is often attached to an experience-based ontology. But it is possible to hold both views; "the centrality and significance [American pragmatists] ascribe to understanding the role that such ideas or beliefs play in guiding our practical interactions with the world does not *compete* with the possibility that those same ideas and beliefs might 'correspond to' or 'agree with' reality."[179] In this project, the scientific realist view holds that scientific knowledge is both instrumentally powerful and 'true' in

[177] Goodstein, "Conduct and Misconduct in Science," 36.
[178] Kavi Joseph Abraham and Yehonatan Abramson, "A Pragmatist Vocation for International Relations: The (Global) Public and Its Problems," *European Journal of International Relations* 23, no. 1 (March 2017): 12.; P. Kyle Stanford, "Instrumentalism: Global, Local, and Scientific," in *The Oxford Handbook of Philosophy of Science*, ed. Paul Humphreys et al. (New York, NY: Oxford University Press, 2016), 320.; Chakravartty, "Scientific Realism."
[179] Stanford, "Instrumentalism: Global, Local, and Scientific," 319.

the sense of approximately congruent with objective material reality.[180] For scientific realists, problem solving and utility result from the discovery of truths.[181]

For SSK and social constructivists, the object of scientific consensus is a social product. For scientific realists, it is a window into the real world. For pragmatists, it is a tool to be utilized and deployed in the pursuit of human ends. In evaluating the influence of existing and emerging scientific consensus on international regimes, this project rejects the social constructivist view, and embraces the pragmatist and especially the scientific realist approach and perspective.

Scientific Realism: Popular Reception and Environmental Thought

Although scientific realism is typically embraced out of a belief that it best reflects actual reality, there are two basic advantages to adopting scientific realism in this project. First, scientific realism represents the 'common sense' or default assumption of most policymakers, which ensures that the project can communicate with those who make critical decisions about global commons management. Indeed, a partial materialist ontology underlies the vast majority of human thoughts and utterances, and is therefore a necessary condition for the intelligibility of the project to the general public.[182] Scientific realism is the "normal understanding" of those outside philosophy and political theory.[183] Adopting this assumption therefore sidesteps any foundational philosophical debates that would prevent the largest and most important audience from engaging with the core argument of this project.

[180] Ibid., 323.
[181] Paul Humphreys et al., eds., *The Oxford Handbook of Philosophy of Science*, Oxford Handbooks (New York, NY: Oxford University Press, 2016), 11.
[182] Searle, *The Construction of Social Reality*, 185.
[183] Ibid., 189.

The second advantage of scientific realism is its compatibility with environmentalist thought. This understanding of the role of science is the "most solid and durable element" in the "intellectual foundation" of environmentalism.[184] The ontological aspect of scientific realism is the "basic template from which environmental problems are defined."[185] This shared template and foundation contributes to the globalization and consolidation of the environmental movement, which is a crucial part of its influence in international policy making.[186] Scientific knowledge is critical in defining the causal relationships behind global environmental problems.[187] It also implies particular types of solutions around which the environmental movement can coalesce.[188] A shared philosophical foundation allows this project to respond to and resonate with major themes in contemporary environmentalism, including urgency, the need for a consciousness shift, environmental justice, modified capitalism, sustainable development, and others. Compatibility with the environmental movement increases the possible impact of the project, because environmentalism is a powerful force for re-orienting the destructive tendencies of modern scientific-technological civilization.[189]

In contrast, wholesale criticisms of scientific realism produced in the social sciences and humanities risk empowering the forces of predatory capitalism. Scientific

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[184] Lynton Keith Caldwell, *Between Two Worlds: Science, the Environmental Movement, and Policy Choice* (Cambridge [England]; New York: Cambridge University Press, 1992), 96.
[185] Ann Hironaka, "Science and the Environment," in *Science in the Modern World Polity: Institutionalization and Globalization*, ed. Gili S. Drori et al. (Stanford, Calif: Stanford University Press, 2003), 250.
[186] Ibid., 261.
[187] O'Neill, *The Environment and International Relations*, 95.
[188] Hironaka, "Science and the Environment," 264.
[189] Daniel Deudney and Elizabeth Mendenhall, "Green Earth: The Emergence of Planetary Civilization," in *New Earth Politics*, ed. Simon Nicholson and Sikina Jinnah (Cambridge, MA: MIT Press, 2016), 43–72.

illiteracy and anti-scientific thinking increasingly pervade American society.[190] Special interests hostile to environmental regulations take advantage of this eroding confidence in science, sometimes explicitly wielding strong social constructivism.[191] This "demotion of science to a mere cognitive style" even infects the scientific classroom, where instructors increasingly hesitate to use terms like 'fact' and 'misconception.'[192] The adoption of a purely social ontology therefore has a practical political disadvantage, in that it undermines the authority of scientific knowledge production, and therefore impedes the transition away from thoughtless destruction, pollution, and unsustainable exploitation.

Technology

'Technology' is a particularly loose and unsettled concept that tends to conflate several distinct phenomena.[193] It encompasses material apparatuses or 'technics' (more commonly, 'devices,' 'artifacts,' or 'machines') but also includes knowledge of how to create and manipulate things (like engineering). This latter meaning of technology bleeds into the concept of science because it includes the intellectual and ideational resources used to design, create, and animate technics, like knowledge, techniques, and skills. The basic idea is that "technology is science in application."[194] Theorists of technology, while admitting the difficulty of precise definition, agree that technology has several basic and essential features. First, technology is designed and deployed to achieve pragmatic

[190] Chris Mooney, *The Republican War on Science* (New York, NY: Basic Books, 2005); Chris Mooney and Sheril Kirshenbaum, *Unscientific America: How Scientific Illiteracy Threatens Our Future* (New York: Basic Books, 2009).
[191] Clive Hamilton, "Why We Resist the Truth About Climate Change" (Climate Controversies: Science and politics, Museum of Natural Sciences, Brussels, 2010); Marcel Kuntz, "The Postmodern Assault on Science," *EMBO Reports* 13, no. 10 (September 18, 2012): 885–89.
[192] Carl Bereiter, "Implications of Postmodernism for Science, or, Science as Progressive Discourse," *Educational Psychologist* 29, no. 1 (January 1994): 3.
[193] W. Brian Arthur, *The Nature of Technology: What It Is and How It Evolves* (New York: Free Press, 2009), 13.
[194] Ziman, *Real Science*, 14.

human purposes.[195] Second, technology harnesses natural phenomena, such as the laws of physics and the availability of raw materials.[196] Third, technology expands the ways humans can access the material world, especially through instruments of observation, measurement, and manipulation.[197] Fourth, technology changes, and with it human abilities to see, do, and control various things. These features define the essence of technology as a variable in human affairs.

While the whole of 'technology' has important implications for the management and use of non-terrestrial spaces, this project will focus on 'technics' – the material apparatuses created by scientists and engineers, which allow humans to identify and access resources.[198] The use of the term 'technology' throughout is not meant to encompass the 'know how' of scientists and engineers, but rather signifies that the natural phenomena exploited by technics are characterized by scientists, who often design and construct instrumentation technology for their own purposes, including observation, measurement, and experimentation. It is technics, however, that directly create new capabilities for humans. The type of capability they support can be used to characterize different technologies: precise observation, harvesting of physical resources, or exploitation of spatial extension resources, among others. Humans invest in particular types of technology depending on their purposes and goals; scientists desiring more precise measurement invest in observation technology, oil companies desiring access to offshore deposits invest in drilling technology, and countries desiring to exploit the

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[195] Langdon. Winner, *Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought* (Cambridge, Mass.: MIT Press, 1978), 7.; Arthur, *The Nature of Technology*, 28.
[196] Daniel R Headrick, *Power over Peoples: Technology, Environments, and Western Imperialism, 1400 to the Present* (Princeton, N.J.: Princeton University Press, 2010), 3; Arthur, *The Nature of Technology*, 51.
[197] Hall, *Mapping the Next Millennium*.
[198] Deudney, "Geopolitics and Change," 106.

vantage point of orbital space invest in satellite launch technology. Thus, the growth of technological capability is driven in large part by the desires and investments of human actors.

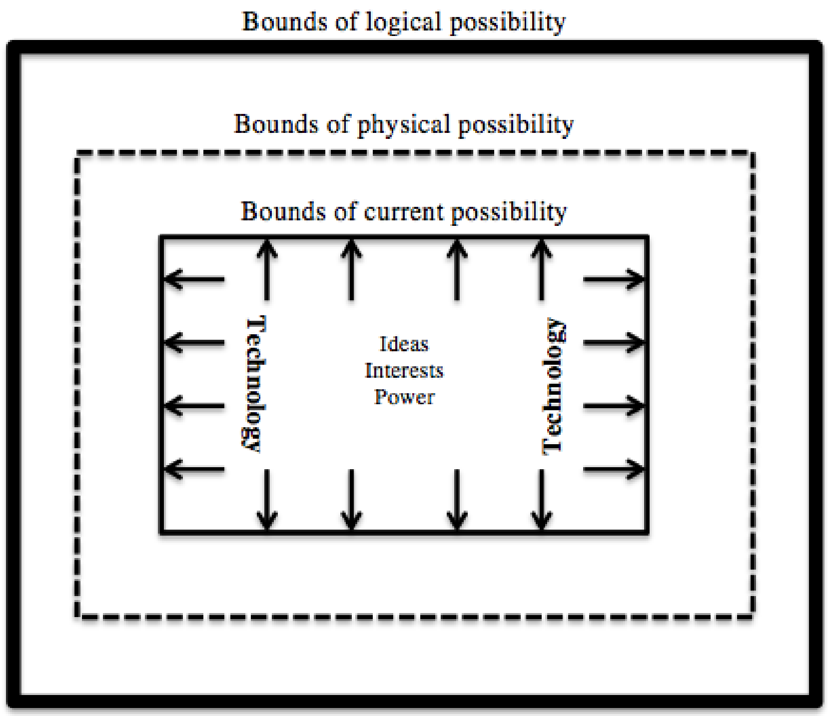

Figure 1 – Universe of Possibility – Science drives technological advancement and characterizes the bounds of physical possibility (which are not fully known)

Current technological capabilities are vast, and future technologies promise even more, but technological possibilities are not infinite. Which technologies are possible is inherently limited. No scientists or engineer can invent a machine that eliminates gravity or creates matter. Scientists, who develop theories like 'Newton's law of universal gravity' and 'the law of conservation of mass,' characterize these limitations. The history of defunct and discredited scientific theories suggests that the basic material features of the universe is still coming into focus, and that we cannot say with certainty which limitations on human activity will be durable in the face of scientific advance and technological innovation. But some physical barriers seem more permanent than others. For example, while human vehicles have broken the speed of sound, they are not likely to match the speed of light. Other examples of physical reality that currently constrain human activities in non-terrestrial domains include: the pressure of the deep sea, the vacuum of outer space, the attributes of the electro-magnetic spectrum, and the low density of air molecules in the upper atmosphere. Technology may or may not be able to surmount these limitations, but science remains critical to defining and understanding them.

Technological Progress

This basic insight about the constraints on technological capability suggests that technological change, taken as a whole and over long periods of time, moves in a particular direction. Technological change can be conceptualized as pushing towards and tracing the boundaries of physical possibility. There are two basic types of technological change: improvement and innovation. Improvements are incremental augmentations of an existing capability, making it more efficient or more effective. Examples include increases in travel speed and the miniaturization of computer chips. Innovations generate new capabilities, and therefore represent more punctuated change. A prototypical example is the creation of nuclear weapons and nuclear power. Other examples include the submarine, heavier-than-air aircraft, and space vehicles. Technological change drives politics in non-terrestrial spaces because of the way it improves existing uses or innovates to create new uses or new forms of access. But technology does not always expand the total amount of access or exploitation; another way to categorize technological change is based on the effect it has on overall capabilities in a given domain. Improvements may amplify existing uses, and innovations may multiply the number of uses. But either might also generate an overall restriction on or reduction in existing uses, especially if the new technological capability improves surveillance and interdiction, which are tools of verification and enforcement.

These general patterns in technological change are often overlooked because the immediate pace and direction of technological advancement is directly determined by the investments of interested parties in research and development of particular technological capabilities. There are many possible technologies that could exist, but do not because no one has an interest in their development. But the physical conditions of possibility are the ultimate determinants of what *can* be invented, even though the interests and resources of human actors determine what *will* be invented. For example, investments in maritime sonar will eventually experience diminishing returns as they bump up against the physical reality that acoustic waves attenuate in the ocean. And no matter how much money the military invests in creating a radar-like sensing apparatus for the oceans, it cannot make the water less opaque to electro-magnetic radiation. The basic point is that patterns of technological change can be understood as fundamentally shaped and channeled by non-contingent obstacles and limitations, which are increasingly identified and characterized by science.

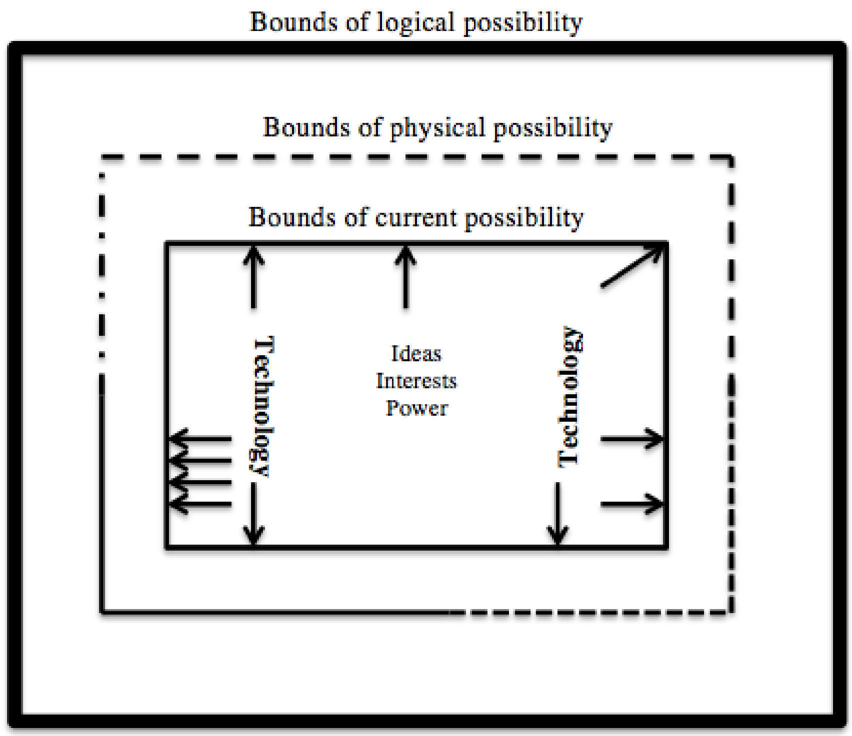

Figure 2 – Determinants of Technological Change – States channel science and technology based on their interests, and this differential investment results in uneven advancement in knowledge and capability.

Although my basic argument assigns an important causal weight to technological change, this theory does not entail 'hard' technological determinism. The most basic reason is that it also ascribes causal force to environmental and geographic influences. Geography, ecology, and technology operate as bounds or constraints on what it is possible to discover and do. The material context determines what can be done, but not what will be done. The set of possible actions contains the set of actual actions. This kind of spatial understanding of causation has precedent: scholars often describe 'proximate' causes, and causal 'over-determination' (read: overlap). Consider an issue-area like deep-seabed mining. Whether it is possible is a technological and geographic question, and concern about its negative impact on seamounts is based on ecological and topographical characteristics of the seafloor. Many political, economic, and legal factors will play an important role in determining whether deep-seabed mining is pursued. But if the water is too deep and the technology is insufficient, even the most powerful actors will be unable to mine the sea floor. Similarly, if scientists discover that nearby seamounts contain biological and genetic resources critical to medical sciences, this may be used to block seabed mining. The extremophiles that live near hydrothermal vents are especially valuable genetically, but their unique properties were not constructed by society or industry. Other aspects of outcomes that cannot be accounted for by ideas, interests, or power include: the composition and distribution of seabed mineral deposits, the ocean currents that connect hypothetical mining sites with seamounts, and the crushing pressure of the deep ocean. These examples indicate why geopolitical theory assigns important causal weight to scientific knowledge of geography and ecology, and technological capability, as limits on what is possible, but allows room for social and political factors to determine the ultimate regime outcomes. In other words, material factors both enable and constrain the operation of social and political influences.

Technology in Geopolitical Theory

A geopolitical approach to global commons regimes contributes to the analysis of Large Technical Systems (LTS) in IR.[199] LTS are networked structures that can stabilize, coordinate, or disrupt social relations. They include submarine telecommunications cables, satellite networks, transnational shipping routes, trawl fisheries, and other patterns of activity in non-terrestrial spaces. These systems are "critical infrastructures in the skeleton of global governance," because they pattern the geographies of practices,

[199] Maximilian Mayer and Michele Acuto, "The Global Governance of Large Technical Systems," *Millennium* 43, no. 2 (January 2015): 660–83.

interests, and consequences.[200] They also happen to "present a clear object of study" for theorizing about international politics, because they are "a practical, graspable and…pressing presence right at the heart of global governance dynamics."[201] After extoling the explanatory and methodological virtues of an LTS-centric analysis, Maximilian Mayer and Michele Acuto describe an additional benefit: LTS as objects of study represent a fruitful opportunity for the transfer of concepts and theories from Science and Technology Studies (STS) to IR.

The STS approach is not, however, the most useful way to engage LTS. The STS approach understands LTS as complex socio-technological systems, but the social phenomena take precedence over material variables in STS explanations. For example, "STS-informed understandings…emphasize the context-dependent, non-universal and inherently uncertain status of knowledge."[202] As a result, knowledge of material structures is ascribed no special epistemological status, and cannot be taken as 'accurate' or non-socially-constructed. The LTS is reduced to its social definition, and plays no special role in explanations. Mayer and Acuto rightly call for a technological turn in IR, but their proposed direction is tentative and inadequate. The problem is an aversion to understanding technology as a structural cause, which is associated with ritual denunciations of environmental and technological determinism (a decades-old bogeyman).[203]

Technology entails an ever-evolving set of available capabilities in non-terrestrial domains, including access, exploitation, and surveillance. The features of technological

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[200] Ibid., 666.
[201] Ibid., 667, 663.
[202] Ibid., 675.
[203] Ibid., 665.

systems define the structural parameters for uses of the ocean and outer space, and influence both what regimes need to do, and what they can do, to be effective. Three features are of particular interest: the level, composition, and distribution of technologies. These characteristics of global technological systems – like submarine cables or satellite networks – shape the content of interests, the consequences of problems, and the set of possible solutions. This project focuses on the character of technologies of access, surveillance, and exploitation, which are highly specific to their associated domains. The pace of technological advancement matters for international politics, partially because it is so difficult to predict in advance. This project focuses on complex technological systems as an evolving structural factor for access and management in non-terrestrial spaces, and therefore an important influence on regime effectiveness.

Conclusion

This chapter has described the fundamental philosophical assumptions of geopolitical theory, for two basic reasons. First, the commitment to a mixed ontology and scientific epistemology makes planetary geopolitics incompatible with, and unintelligible to, large portions of existing scholarship in the social sciences. Second, the nature of scientific and technological change, as described here, demonstrates some advantages to a geopolitical approach. Because the project shares intuitive philosophical assumptions and resonates with environmentalism, it is accessible to a broad audience. But more importantly, geopolitical theory acquires significant analytical traction from the recognition that science and technology move in particular directions, which are defined by the physical features of the material world. The next chapter addresses how the philosophical assumptions of geopolitical theory inform the methodology of geopolitics, and describes the relationship between this approach and existing theories of global commons regimes.

A Geopolitical Theory of Global Commons Regimes: Methodology and Propositions

Despite decades of international diplomacy and regime building, global environmental problems continue to increase in number, scale, scope, and consequence. This project begins from the premise that existing approaches to global governance in non-terrestrial spaces have not produced functional regime designs. With the emergence of new and dangerous problems like space debris and ocean acidification, the situation is increasingly urgent. This project pursues a materialist geopolitical approach to explaining regime failure, which in this chapter is delineated and differentiated from the existing literature, and defined in broad outlines.

The first section begins by addressing the concept of a 'global commons,' and how it relates to the non-terrestrial domains that are the subject of this project. It then reviews existing theories of regimes from the realist, neo-liberal institutionalist, and constructivist schools of thought in International Relations (IR). This section demonstrates the inadequacies of existing theories, while noting the ways that they implicitly, and in an ad hoc way, rely on material contextual variables (geography, ecology, technology). The next section describes the methodology of planetary geopolitics, and unpacks the role of temporal and spatial structures in the overall critique of existing regime design. The third section addresses the thing to be explained: the ineffectiveness of existing global commons regimes. This includes the meaning of 'effectiveness,' the conditions that are usually understood to support effectiveness, and the conditions of effectiveness from the perspective of planetary geopolitics. The concluding section identifies three 'regime pathologies,' or features of regime design that contribute to ineffectiveness over time. This chapter sets the stage for the more targeted evaluation and analysis of the case chapters.

Regime Theories

The study of global environmental governance has been prominent in International Relations (IR) and related fields since the 1980s, and is noted for its special focus on the effectiveness of regimes. Material contextual variables (geography, ecology, technology) are present in many existing accounts of global commons regimes (GCRs), but their structural significance has been largely overlooked. Changes in scientific knowledge and technological capability tend to be treated in an ad hoc, unsystematic way that fails to register insights about their influential role for management in non-terrestrial spaces. This chapter draws out the implicit material contextual variables from existing theories, and weaves them together into a coherent geopolitical theory of GCRs. After a note on the term 'global commons,' this section reviews the dominant strands of regime theory applied to the non-terrestrial domains in order to point out (a) their general deficiencies, and (b) their ad hoc reliance on material-contextual variables. The next section describes the methodology for extracting, augmenting, and systematizing these variables into a novel and complementary theory of GCRs.

'Global Commons'

The ocean and outer space are commonly referred to as 'global commons,' but are more accurately characterized as 'non-terrestrial domains.' 'Global commons' is a political geography constructed by humans, which overlays and interprets 'brute' physical facts.[204] Most perspectives on GCRs take as a given, or an assumption, that non-terrestrial spaces are global commons. Yet many authors define the global commons in a

[204] John Vogler, "Global Commons Revisited," *Global Policy* 3, no. 1 (February 2012): 61.

contingent way, as areas that are not under national, sovereign, or singular jurisdiction.[205] The term is often used to contrast these areas with the political geography of the territorial state system. It may be true that governance regimes construct the ocean or outer space as a global commons, but that does not mean there are not other ways to understand non-terrestrial planetary spaces. Defining a space by its political geography, instead of its natural and technological material geography, begs the question of regime theory by conflating a socially-constructed political arrangement with an intrinsic attribute of what is to be governed.

The main schools of thought in IR with which scholars approach the topic of GCRs are Realism, neo-liberal institutionalism, and constructivism. Each has a separate understanding of the 'global commons' as an object of management. For Realists, 'global commons' are operational environments for both military competition and economic exchange. For Realism, 'global commons' must be dominated to ensure smooth flows of power and production.[206] For neo-liberal institutionalists, the 'commons' are places that contain 'common pool resources' (CPRs). In analyzing CPRs, neo-liberal institutionalists consider whether resource are 'rival' or 'subtractable' (they can be depleted) and their users are 'non-excludable,' so they pose distinct types of management challenges.[207] The 'global commons' are places where CPRs can be accessed by anyone in the international

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[205] Magnus Wijkman, "Managing the Global Commons," *International Organization* 36, no. 3 (Summer 1982): 512; John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 1; Seyom Brown et al., eds., *Regimes for the Ocean, Outer Space, and Weather* (Washington: Brookings Institution, 1977), 1; Scott Jasper, ed., *Securing Freedom in the Global Commons*, Stanford Security Studies (Stanford, Calif: Stanford Univ. Press, 2010), 2.

[206] Vogler, "Global Commons Revisited," 65.; Barry R. Posen, "Command of the Commons: The Military Foundation of U.S. Hegemony," *International Security* 28, no. 1 (July 2003): 5–46.

[207] Susan J Buck, *The Global Commons an Introduction* (Washington, D.C.: Island Press, 1998), 5; Marvin S. Soroos, *The Endangered Atmosphere: Preserving a Global Commons* (Columbia, SC: Univ. of South Carolina Press, 1997), 17–18.

community. But the existence of CPRs implies a particular property regime, one where resources can be accessed and exploited, but not owned. But property regimes are created, not discovered, by humans. The constructivist school understands the global commons as constructed international spaces, and they hold that Realism and neo-liberal institutionalism, as well as materialist approaches, err in naturalizing what are in fact socially constructed entities.[208] In general, most constructivists reject the idea that there is a separate, prior, and natural material context that represents an inherent and influential aspect of these spaces.

Whether the objects of governance are non-terrestrial planetary spaces or global commons matters for the literature on regimes. Scholars of global environmental governance frequently refer to the nature or structure of the "problem," the "resource," the "issue-area," the "realm" or the "situation."[209] Problem structure motivates regime design and has implications for regime effectiveness, by determining what needs to be done and what can be done in a certain area. But there is no consensus about how to define problem structure. Reducing structure to 'global commons' oversimplifies the geographies of access, exploitation, and management in non-terrestrial spaces. For example, Realists overlook the spatial features of ecosystems, and neo-liberal institutionalists conflate the unique challenges of common pool vs. common sink resources.[210] The geopolitical approach provides a more complete understanding of the influences of material contexts on the global governance of the ocean and outer space.

[208] Philip E Steinberg, *The Social Construction of the Ocean* (Cambridge; New York: Cambridge University Press, 2001).
[209] Barrett, *Environment and Statecraft*, xii; Godwin and Shepard, "Forcing Squares, Triangles and Ellipses into a Circular Paradigm: The Use of the Commons Dilemma in Examining the Allocation of Common Resources," 277; Haggard and Simmons, "Theories of International Regimes," 498; Brown et al., *Regimes for the Ocean, Outer Space, and Weather*, 3; Young, "Land Use, Environmental Change, and Sustainable Development: The Role of Institutional Diagnostics," 82.
[210] Vogler, *The Global Commons*, 3.

While the designation of a ‘problem’ is a human construct, the structure of a problem like ocean acidification or space debris is significantly shaped by the material context. This includes the geography of global technological systems, which contains “mundane heterogeneity” as well as important “clusters of technically stabilized (and evolving) relations at a multitude of scales.”[211] The geopolitical approach thereby more accurately describes the complexity of non-terrestrial spaces, “sketching out a deeper and more complex, but still manageable, landscape for IR.”[212] Just as existing theories miss the full story about the object of global governance, their accounts of regime formation and operation overlook and under-emphasize the planetary material context.

Most of the literature on GCRs focuses on the distribution of power (Realist), interests (neo-liberal), and ideas (constructivist) as explanations for political outcomes. These schools of thought are so distinct and powerful that – 25 years after penning the consensus view of regimes – Stephen Krasner revised his initial definition to account for three separate ways of defining them.[213] The Realist view eliminates ‘rules’ from the content of regimes and argues that their principles, norms, and decision-making procedures merely reflect the interests of the most powerful actors. The neo-liberal institutionalist view keeps rules, and describes regimes as solutions to ‘market failures,’ understood as situations where the market fails to provide a good for which there is a demand. The constructivist view of regimes simply sees them as clusters of international norms. Each of these understandings of what a regime is places them in the context of a larger international order, whether it is the balance of power, the global economy, or

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[211] Maximilian Mayer and Michele Acuto, “The Global Governance of Large Technical Systems,” *Millennium* 43, no. 2 (January 2015): 677–78.
[212] Ibid., 678.
[213] Stephen D. Krasner, Theory Talk #21: Stephen Krasner on Sovereignty, Failed States and International Regimes, interview by P. Schouten, October 19, 2008.

pervasive ideas and ideologies. These power-structural, institutional, and normative-ideational contexts are critical for explaining many aspects of GCR emergence and operation, but they do not explicitly incorporate the material context on, over, and through which all of international politics occurs – the planet Earth.

Realist International Relations Theory

The Realist school of IR is highly skeptical of the independent influence of institutions on state behavior. Realists describe regimes as weak, ephemeral, or unenforceable, and thus have actually paid little attention to the politics of regimes for non-terrestrial spaces.[214] Realists believe that states pursue relative gains, and are unwilling or uninterested in cooperating for the sake of absolute gains. Regimes are simply another forum in which to exercise power, and can either reaffirm or shift existing power relations.[215] For example, Realists would tend to describe the 'common heritage' principle as an attempt by developing states to shift the economic benefits of resource extraction in their favor. But in general, Realists emphasize that many of the norms and rules governing the global commons started out as American preferences, practices, or policies.[216] GCRs institutionally reinforce a preferential balance of power, including strategic and economic benefits for powerful actors. Realists understand violations of regime dictates – such as China's rampant flouting of international fishing regulations – as evidence of rising and revisionist powers asserting their own national interests. In such cases, regime ineffectiveness is a product of a shifting balance of power. Realists do admit that power can be wielded in the service of the common good and collective

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[214] John J. Mearsheimer, "The False Promise of International Institutions," *International Security* 19, no. 3 (Winter /95 1994): 5–49.
[215] Kate O'Neill, *The Environment and International Relations*, Themes in International Relations (Cambridge, UK ; New York: Cambridge University Press, 2009), 76.
[216] Vogler, *The Global Commons*, 209.

interests, but only in cases where doing so would establish a valuable leadership role that reaffirms a state's power.[217]

Scholars in the sub-field of global environmental politics generally view Realism as having little to contribute, because it is skeptical of the possibility of meaningful international cooperation to mitigate shared vulnerability and achieve collective interests.[218] But Realism does offer important insights about the role of material variables in shaping the patterns and content of interests and practices. However, these insights are all framed in terms of relative power and national interests. For Realists, the most important question about material factors is who has more or less of them. Thus Realists view power as significantly a function of geography. They analyze factors like resource distribution, coastal topography, and location at the equator, which provide states with domain-specific forms of power. But Realists overlook the ways that geography creates stakeholder groups, such as those most vulnerable to sea-level rise, those with oil and gas in their continental shelves, and those with favorable siting for space launches. These groups may create novel coalitions for regime building and enforcement, because of their particular shared interests.

Realists also view technology as a means to power. Access to non-terrestrial resources is technology dependent, and technology represents power within a given domain.[219] Because technology can be costly and complex, the burdens of research, development, manufacture, and deployment create asymmetrical forms of access. Container ships, deep-sea trawlers, submarines, satellites, space vehicles, and other

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[217] Stephen D. Krasner, "Structural Causes and Regime Consequences: Regimes as Intervening Variables," *International Organization* 36, no. 2 (Spring 1982): 197–98.
[218] O'Neill, *The Environment and International Relations*, 11.
[219] Jasper, *Securing Freedom in the Global Commons*.

access technologies require significant expenditure and advanced enabler technologies (such as engineering software). Realists focus on the distribution of technology, and especially the unequal power potentials inherent in advanced technology. But they overlook technological composition as a key variable, which directly influences patterns of practices in the ocean and outer space.[220] New technological uses create vested interests in maintaining those practices. For Realists, technology is a tool of power. But states cannot simply pick the technological practices they prefer or object to – technological development independently conditions what practices can be pursued, and technological momentum makes it difficult to prohibit the use or dissemination of unfavorable technologies.

Realists tend to be skeptical about the verification and enforcement aspects of international treaties, but this is also a technology-dependent question. Domain-specific forms of power can be used to monitor, verify, and control. New information technology may radically alter the prospects for surveillance in some use-activities (examples include Automatic Identification Systems for container ships, aerial and submarine drones, and chemical tracing). In some cases the ready visibility of some technological uses makes verification easier, such as in the case of ship design requirements for minimizing marine pollution.[221] Realists characterize technological advances as an increase in state capacity and power. But this outcome is not the only possible result because technological capabilities may also contribute to constraining state power.

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[220] Daniel Deudney, *Bounding Power: Republican Security Theory from the Polis to the Global Village* (Princeton: Princeton University Press, 2007), 77–78.
[221] Ronald B. Mitchell, *Intentional Oil Pollution at Sea: Environmental Policy and Treaty Compliance*, Global Environmental Accords Series (Cambridge, Mass.: MIT Press, 1994).

Realists recognize the importance of scientific knowledge production for state power. During the Cold War, great power competition drove data accumulation and theory development in an effort to improve the performance of militaries in their operational environments. In order to monitor the movements and capabilities of weapons, states employed oceanographic, atmospheric, and geophysical sciences.[222] Scientific findings also constitute a kind of authoritative knowledge that can be wielded in favor of preferred outcomes. For example, new scientific knowledge about the negative effects of high levels of radioactivity on the environment helped the Soviet Union effectively criticize the West for dumping nuclear waste into the ocean (despite continuing the practice themselves).[223] Yet Realists overlook the ways that scientific knowledge production can reshape the content and boundaries of 'national interests.' In particular, scientific knowledge can re-frame issues by suggesting a different temporal or spatial scale, thereby generating new types of interests. For example, unrestricted carbon emissions seem in the short-term interest of specific sectors of the US economy. But from a broader and longer-term perspective, scientific findings show that unrestricted carbon emissions, causing sea-level rise and more severe storms, are not in the interests of the United States.

Realism is not well-suited to analyzing the failures of global commons regimes in the governance of non-terrestrial spaces. It defines 'effectiveness' in an overly narrow way, to encompass only the interests of the dominant powers. This means that Realists provide a simplistic explanation of ineffectiveness as solely the result of a shifting

[222] Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford: Oxford Univ. Press, 2013).
[223] Jacob Darwin Hamblin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, N.J.: Rutgers University Press, 2008).

balance of power. But power shifts alone cannot explain the dysfunction of GCRs. Major changes in relative power, such as the collapse of the Soviet Union, the rise of China, and the emergence of threatening non-state actors, have had no particular impact on the problem of ocean acidification, for example. Although Realists recognize that national interests are modified by geography and technology, they treat interests as relatively static and nation-centered. But interests are dynamic and often collective; stakeholder groups emerge over time from scientific knowledge production and technological advance. Planetary geopolitical theory shares with Realism the belief that material reality has explanatory power for explaining what states can do, and want to do, but offers to do so in a much fuller and more serious way. First, the project considers the importance of the material context for practices, interests, and problems as a whole, as opposed to being concerned solely with the geopolitical determinants of state power. Second, the planetary geopolitics approach incorporates the important material variable of ecology, which is almost entirely overlooked by Realists.

Neo-liberal Institutionalism

The prevailing mainstream approach to regimes among IR theorists is neo-liberal institutionalism. Members of this school are optimistic about the potential of GCRs to facilitate meaningful cooperation.[224] Although the term 'neo-liberal institutionalism' is criticized as mere "scholarly branding," it captures the idea that states can achieve collective gains through institutionalized cooperation.[225] Under this view, states create international institutions out of self-interest, to coordinate and collaborate with one

[224] Krasner, "Structural Causes and Regime Consequences: Regimes as Intervening Variables," 195; Andreas. Hasenclever, Peter Mayer, and Volker Rittberger, *Theories of International Regimes* (Cambridge; New York: Cambridge University Press, 1997), 4; Vogler, *The Global Commons*, 18.
[225] Christian Reus-Smit, Duncan Snidal, and Arthur A. Stein, eds., "Neoliberal Institutionalism," in *The Oxford Handbook of International Relations* (Oxford ; New York: Oxford University Press, 2008).

another in order to achieve individual and collective gains. Unlike Realists, neo-liberal institutionalists believe that "states are interested in absolute gains for the entire community," and will seek out new ways to achieve collective benefit.[226] Global governance, then, is "essentially a matter of administration."[227] But different constellations of interests require different institutional forms, and therefore neo-liberal institutionalists are concerned with the question of institutional design.

Institutionalists categorize goods based on the rivalry of consumption and the excludability of users, and argue that the anarchic state system fails to provide certain kinds of collective goods. The solution to this is a treaty design that restructures incentives to stimulate efficient and/or sustainable use activities.[228] Commons regimes, for the neo-liberal institutionalist, are rationally designed institutions that serve mutual interests by overcoming collective action problems. These interests are usually economic but sometimes related to sovereignty. Collective action problems are difficult to resolve because they "pit individual against collective rationality."[229] The 'market failures' regimes typically seek to overcome are production externalities and the provision of public (non-rival and non-excludable) goods.[230] Because the international system is anarchic, neo-liberal institutionalists argue that success requires both inducements and verification. In addition to minimizing transaction costs, regimes are responsible for monitoring compliance, increasing transparency, and adopting other mechanisms that

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[226] O'Neill, *The Environment and International Relations*, 49.
[227] Buck, *The Global Commons an Introduction*, 9.
[228] Brown et al., *Regimes for the Ocean, Outer Space, and Weather*.
[229] Andreas Hasenclever, Peter Mayer, and Volker Rittberger, "Interests, Power, Knowledge: The Study of International Regimes," *Mershon International Studies Review* 40, no. 2 (October 1996): 205.
[230] Mark W. Zacher, *Governing Global Networks: International Regimes for Transportation and Communications*, Cambridge Studies in International Relations 44 (Cambridge ; New York: Cambridge University Press, 1996), 3.

reduce cheating.[231] Effectiveness, then, is a matter of getting the incentives right. Even if GCRs are not successful at constraining harmful activities, institutionalists argue that they may create a convergence of interests through increased transparency, and by serving as a forum for consensus building.

The rational pursuit of interests drives regime formation and operation. But in general, the question of interest content is a difficult one for neo-liberal institutionalists. Domestic-level interests are aggregated into diplomatic positions (state preferences) through different systems of decision-making and opinion-aggregation. Idiosyncratic domestic contexts, such as the powers and preferences of different industries or particular bureaucrats, or cultural attachments to particular activities, make it extraordinarily difficult to generalize about the content of interests on the state-to-state level. Institutionalists posit the existence of mutual, collective, and harmonious interests, but set aside questions about why such interests exist, when and how they emerge, and whom they include.

[231] O'Neill, *The Environment and International Relations*, 10.

Geopolitical theory helps explain interest formation. Regimes are about what actors *may* do, in the sense of permission, legitimacy, and social acceptability. The material context defines what actors *can* do, in the sense of physical possibility. A third category of activities is those actors *want* to do, because they have a specific, conscious interest in doing them. The concept of interests sits at the heart of both neo-liberalism and geopolitical theory, because both presuppose that human agents are pragmatic, self-interested, and rational in their pursuit of basic ends (like security, welfare, and prosperity), and in the face of fundamental and recurring problems of distribution and management.[232] Domain-specific interests are formed when basic human desires interact with the physical possibilities of a particular planetary space. Because it would be irrational to have an interest in a logically or physically impossible activity, the

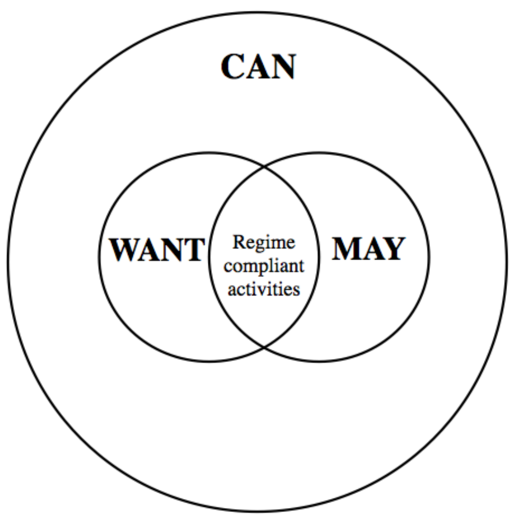

Figure 3 – Interest Formation

[232] Daniel Deudney, "Geopolitics and Change," in *New Thinking in International Relations*, ed. Michael W. Doyle and G. John Ikenberry (Boulder: Westview, 1997), 100.

constraints of the material context shape the content of actor interests. What is possible, or what seems possible, limits the category of desirable activities. Regimes also attempt to shape actor interests, by legitimating particular activities and prohibiting others. Whether they are successful is a question of regime effectiveness, the subject of a later section. The key point here is that interest formation is a site of productive engagement between neo-liberal and geopolitical IR theory.

The material context shapes the content and distribution of interests in non-terrestrial spaces. Neo-liberal institutionalists recognize that most institutional cooperation in the ocean and outer space is based on the awareness of mutual vulnerability to problems like over-fishing, piracy, space weapons, and environmental degradation. These vulnerabilities did not always exist, but they were in significant measure created by technological developments, and identified and characterized by scientific activity.[233] All vulnerabilities are not created equal, however, and scientific knowledge serves as the basis for risk assessments and cost-benefit calculations at different time scales. Aside from mutual vulnerability, the other major driver of GCRs is the potential for collective benefit. In non-terrestrial domains, technology and technological capability mediate access to resources and enable new use-activities, thereby creating specific and definable interests. Although these types of access often create individual interests in extractive or other activities, the material context shapes collectivities of interest. For example, diplomatic coalitions often form along technological or geographical lines: the first space-farers, landlocked vs. coastal vs. maritime states, and the partnership of Arctic indigenous groups and small island developing states as the first victims of sea-level rise. Geopolitical variables shape the

[233] Vogler, *The Global Commons*, 132.

timing, content, and distribution of interests in a patterned, observable way. Yet neo-liberal institutionalism simply takes such interests as background.

Geopolitical theory also employs a distinction between actual-interests and perceived-interests. As mentioned, neo-liberal institutionalists recognize that shared vulnerability drives regime formation, and is often identified and characterized by science. But sometimes, the scientific community identifies an interest that the political community has ignored. In the case of climate change, for example, humans have an interest in decreasing carbon emissions even if they do not recognize or acknowledge it. But there are also cases where scientists are slow in recognizing a shared vulnerability. For example, asteroid collision was not considered a threat by anyone until the second half of the 20th century. I hypothesize that regime ineffectiveness occurs when a perceived interest is not satisfied because of regime design, or when an actual interest is not perceived because of regime design.

This project partially relies on the tools of institutionalism to explain the persistence of a mismatch or misfit between scientific knowledge, technological capability, and the specific content of GCRs. When the material context changes, but institutions do not adjust, the reason is often a kind of institutional inertia or 'lock-in' effect. When institutions do adjust to account for new understandings or capabilities, this shift can be understood as a 'critical juncture,' where the inadequacy of an existing regime becomes obvious and acute. These are cases where an interest is perceived, but either is or is not responded to and accounted for by the regime.

Commons Management

Commons management is a subset of institutionalist literature that focuses on the challenges of establishing coherent and enforceable property regimes in a shared resource system. Property can be understood as a bundle of rights, including access, extraction, exclusion, and transfer.[234] Creating and enforcing property regimes, which define ownership of resources, requires addressing "issues of allocation, measurement, boundaries, and enforcement."[235] Because non-terrestrial domains have different logics and patterns than terrestrial spaces, their cooperative management in a condition of inter-state anarchy is a special problem for the state system. Theories of commons management are typically based on a liberal political economy, insofar as they are concerned with how different property and use regimes fare in a world of individualistic and self-interested actors.

The 'commons' concept is applicable to all scales, and it is often the case that discussion of global commons merely increases the scale of concepts and ideas associated with the local commons.[236] Eleanor Ostrom's *Governing the Commons* (1990) is the seminal work on small-scale commons management, and its insights about the conditions for effective cooperative governance have been applied in a limited way to the global commons. There are good reasons to believe, however, that the unique challenges and opportunities of global commons management severely limit comparisons with local institutions.[237] Ostrom's book, while illuminating, often reads like a discussion between anthropologists and economists about what makes individuals cooperate. These local commons depend on 'vernacular knowledge' whereas global commons regimes are more appropriately "science driven."[238] On the planetary scale, the personality of state and

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[234] Buck, *The Global Commons an Introduction*, 5.
[235] Eric Brousseau et al., "Introduction: Global Environmental Commons: Analytical and Political Challenges in Building Governance Mechanisms1," in *Global Environmental Commons*, ed. Eric Brousseau et al. (Oxford University Press, 2012), 1–28.
[236] Vogler, "Global Commons Revisited," 61.
[237] Vogler, *The Global Commons*, 214–20.
[238] Ibid., 217.

corporate actors, the context of anarchy, the diversity of populations, and the sheer distance between actors requires additional insights from IR to generate useful prescriptions for cooperative management.

Table 1: Some differences between local natural resources and global commons that may be important for governance

		Local natural resources	Global commons
1	Geographic scale	Local	Global
2	Number of resource users	Tens to thousands	Millions to billions
3	Salience: actors' awareness of degradation	Resource use is conscious purpose; resource provides major portion of livelihood	Resource degradation is unintended byproduct of intentional acts; actions causing degradation are of low importance for most users
4	Distribution of interests and power	Benefits and costs mainly internal to group of appropriators	Significant externalities between appropriators and others across places and generations; differences of interest and power among classes of appropriators
5	Cultural and institutional homogeneity	Homogeneous	Heterogeneous
6	Feasibility of learning:	Good	Limited
6a	Regeneration of degraded resource	Renewable over less than a human generation	Regeneration over more than a human generation
6b	Ease of understanding resource dynamics	Feasible without extensive scientific training	Scientifically complex with limited predictive ability
6c	Stability of resource dynamics	Stable, though variable	Dynamic systems with changing rules
6d	Ability to learn across places	Possible	Difficult

Figure 4 – Differences between local and global commons; From Paul C. Stern, "Design Principles for Global Commons: Natural Resources and Emerging Technologies." International Journal of the Commons 5, no. 2 (August 2011): 216.

Constructivism and Epistemic Communities

The challenge to scientific epistemology in the 1970s and 1980s, from post-modernism and social constructivism, set the stage for the emergence of a new school of IR theory, known as constructivism.[239] In the 1990s, a new body of theory emerged to

[239] Peter M Haas, *Epistemic Communities, Constructivism, and International Environmental Politics* (Taylor and Francis, 2015), 3.

challenge the Realist and liberal paradigms.[240] Constructivist (sometimes referred to as 'cognitivist' or 'idealist') theories of international politics display less unity in their assumptions and assessments of international institutions, but they are united in emphasizing the role of non-material ideational variables and in adopting a sociological meta-theoretical orientation.[241] As such, constructivism is a clear foil for a geopolitical approach, because it "emphasizes the meanings that are assigned to material objects, rather than the mere existence of the objects themselves."[242] Although some constructivists admit to the existence of an objective material world, the "irreducible core" of constructivism is the view that all of accessible reality is socially constructed. Social meaning making constitutes any and all patterns, even causal relationships, and material objects do not directly affect outcomes. This constructivist approach is now "broadly accepted," and the single largest school of IR theory, according to some reckonings. [243]

A constructivist approach to GCRs highlights the wider context of "persuasive ideas, collective values, culture, and social identities."[244] Ideas about regime goals and values, for example, might be explained by the application of ideologies from the larger international context to specific issue areas. Regimes might themselves generate ideas about the domains they seek to manage, and socialize users and members into particular

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[240] Jonathan Cristol, "Constructivism".
[241] Hasenclever, Mayer, and Rittberger, *Theories of International Regimes*, 2.
[242] Cristol, "Constructivism."
[243] 22.5 percent of respondents to the 2014 Teaching, Research, and International Policy (TRIP) Faculty Survey identified their approach as constructivist, with no paradigmatic approach as the only larger category, Ian Hurd, "Constructivism," in *The Oxford Handbook of International Relations*, ed. Christian Reus-Smit and Duncan Snidal, Oxford Handbooks of Political Science (Oxford ; New York: Oxford University Press, 2008), 301.
[244] Jack Snyder, "One World, Rival Theories," *Foreign Policy*, 2004, 59.

roles, preferences, and identities.[245] Whether ideas are exogenous influences on regime formation and operation, or they are produced and disseminated by regime dictates and activities, ideational variables rely on the fact that inter-subjective concepts, or "shared meanings," are (re)produced by the circulation of discourses. The focus on discourse, ideas, and norms means that constructivists do not privilege the state, but instead argue that other actors are influential and relevant.[246] Any actor that promotes and disseminates new ideas can be a key actor.[247]

Constructivists also advance a general explanation for what leads states to cooperate. Unlike the neo-liberal institutionalist story about solving collective action problems, or the Realist competition for relative gains, constructivists see a world of actors pursuing social ends. Norms, values, ideas, and identities impact the formation of regime goals. For constructivists, interest formation occurs through socialization and internalization of ideas, and interests are often defined by the pursuit of recognition, prestige, legitimacy, or communal membership.[248] For example, the common goals of sustainability and equity can both be understood as assertions about fairness and justice in the international community, present and future. Because non-terrestrial planetary spaces provide important resources – including food, fresh air, and a stable climate – to billions of people, the trade-offs involved in their exploitation represent a choice about the distribution of basic goods; "virtually all environmental decisions raise ethical dilemmas."[249] The developing world, through the Group of 77 (G77) coalition and the

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[245] O'Neill, *The Environment and International Relations*, 76.
[246] Ibid., 11.
[247] Snyder, "One World, Rival Theories," 59.
[248] Hurd, "Constructivism."
[249] Fen Osler Hampson and Judith Reppy, eds., *Earthly Goods: Environmental Change and Social Justice* (Ithaca, N.Y: Cornell University Press, 1996), 5.

'New International Economic Order' (NIEO) movement, has injected ideas about historical injustice and contemporary reparations into the formation of GCRs. Examples include the 'common but differentiated responsibilities' principle, the inclusion of technology transfer provisions, and designations of 'common heritage.' Obligations to future generations, and to the planet itself, also animate discussions about how and why activities in the ocean and outer space should be regulated; the timeframe, spatial scale, and membership of the relevant community is constantly being debated and negotiated. But these evolving norms and values do not control or fully determine the content of interests and goals in non-terrestrial domains.

Constructivism suggests that ideas only affect international regimes when or after they have been transferred to policymakers in some way.[250] The 'epistemic communities' approach, first introduced by Peter Haas in the 1990s, explains the role of scientists in concentrating, fleshing out, legitimating, communicating, and advocating for particular ideas (described as "consensus"). An epistemic community is defined as "a knowledge-based transnational network of professionals holding political power by cognitive authority."[251] Epistemic communities are bound together by shared normative beliefs, causal beliefs, notions of validity, and a common policy enterprise.[252] These transnational networks of scientific experts use their authoritative position to shape the content of regimes. Although an 'epistemic community' is ultimately a theory deployed by constructivists (and not a paradigm in its own right), its visibility in IR and relationship to

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[250] Peter M. Haas and Casey Stevens, "Organization Science, Usable Knowledge, and Multilateral Environmental Governance," in *Governing the Air: The Dynamics of Science, Policy, and Citizen Interaction*, ed. Rolf Lidskog and Göran Sundqvist (Cambridge, Mass.: MIT, 2011), 131.
[251] Rolf Lidskog and Göran Sundqvist, "The Role of Science in Environmental Regimes: The Case of LRTAP," *European Journal of International Relations* 8, no. 1 (2002): 82.
[252] Peter M. Haas, "Introduction: Epistemic Communities and International Policy Coordination," *International Organization* 46, no. 1 (Winter 1992): 3.

the project suggests the need for a separate discussion. The epistemic communities approach is currently the "most influential model of the role of expert knowledge."[253]

Epistemic communities are important for GCRs because the consensual knowledge they produce defines problems and shapes interests. More specifically, scientific groups identify causal relationships and interconnections between issues.[254] Epistemic communities are the "principal channel" through which understandings about cause are applied to international regimes.[255] Causal relationships – like that between carbon emissions and climate change – define collective problems and create specific interests. This perspective is largely congruent with the geopolitical approach described above, because it explains *how* scientific knowledge comes to impact regimes. But the epistemic communities approach thus far has focused almost exclusively on the social factors involved in the dissemination of scientific knowledge. Scientific ideas are "chosen" from a "consensual knowledge base" depending on the number of available ideas, their simplicity, potential for political coalitions or political gain, and alignment with pre-existing beliefs.[256] When ideas are successfully diffused, it is not because of their content, but because specific political, social, and economic channels were available and accessed by authoritative experts. The epistemic communities approach rejects the rationalist or policy-analytic claim that major problems exist independently of researchers, are discovered by them, and that this discovery automatically creates incentives for problem resolution. Scientific knowledge becomes a guide for action because it is wielded and disseminated by expert authorities.

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[253] O'Neill, *The Environment and International Relations*, 97.
[254] Haas, *Epistemic Communities, Constructivism, and International Environmental Politics*, 9.
[255] Ibid., 4–5.
[256] Ibid., 10, 7.

Haas and co-author Casey Stevens explicitly acknowledge that in order to really be influential, scientific consensus must be developed independently of political processes, and be insulated from political pressures. For example, they argue that scientific bodies should control their own agenda, and be composed of experts chosen because of their scientific qualifications, not their national identity.[257] Keeping the development of scientific knowledge as a distinct, separate, and prior phase (before policymaking) produces "usable" knowledge that is "likely to be adopted by decision makers."[258] Knowledge is usable insofar as it is credible, legitimate, and salient. All three of these features are social characteristics. Credibility requires consensus among scientists.[259] Salient information is "timely and is organized on a politically meaningful timescale."[260] In other words, the production of scientific knowledge must be separated from politics not to ensure that it is true, but to guarantee that it is believable. This is the normative element of the epistemic communities approach: scientific communities provide better advice to policymakers, because of their expert status and minimal political bias.[261]

In focusing on the social aspects of expertise and influence, the epistemic communities literature "brackets the production of knowledge itself."[262] Materialist geopolitical theory challenges the wide room for maneuver implied by the constructivist notion of "shared meanings" or "shared understandings," instead suggesting that the

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[257] Rolf Lidskog and Göran Sundqvist, "When Does Science Matter? International Relations Meets Science and Technology Studies," *Global Environmental Politics* 15, no. 1 (February 2015): 4.
[258] Haas and Stevens, "Organization Science, Usable Knowledge, and Multilateral Environmental Governance," 128.
[259] Lidskog and Sundqvist, "When Does Science Matter?," 4.
[260] Haas and Stevens, "Organization Science, Usable Knowledge, and Multilateral Environmental Governance," 130.
[261] Haas, *Epistemic Communities, Constructivism, and International Environmental Politics*, 8.
[262] Bentley B. Allan, "Producing the Climate: States, Scientists, and the Constitution of Global Governance Objects," *International Organization* 71, no. 01 (2017): 134.

contours of material reality, as revealed by science and accessed by technology, represent a set of severe and important bounds or constraints on meaning-making. These constraints operate in two ways. First, the bounds of the material context channel our experience of the planetary domains in which we operate. For example, most humans can only see the deep ocean through the video streams of robotic submersible vehicles. Second, scientific knowledge production is keyed to the contours of the material context, and science enjoys a special status as authoritative fodder for meaning making. In both cases, our shared understandings of the ocean and outer space are channeled and shaped by the material context. Geopolitical theory puts the material core of inter-subjective understandings at the center of analysis, and highlights the mechanisms through which the material context shapes and constrains the trajectory of ideational variables.

The geopolitical approach takes two stances that differentiate it from constructivism and the epistemic communities approach. First, the material context is a structural influence on interests and ideas. The key weakness of the constructivist approach is its difficultly explaining the structures and conditions that cause change in ideas, norms, and values.[263] While this project could not possibly identify all relevant causes of ideational change, the geopolitical approach does offer some important insight about the nature of scientific knowledge production. Second, the structural influence of the material context explains why scientific knowledge has a special epistemic status, and is therefore a powerful influence on and source of interests and ideas. Most theorists agree that new ideas can change the calculation of interests, but the source of new ideas is disputed.[264] Constructivists generally deny that scientific knowledge production can

[263] Snyder, "One World, Rival Theories," 59.
[264] O'Neill, *The Environment and International Relations*, 11.

independently shape the social and discursive world; “Sharers in a common scientific worldview are more likely to perpetuate than deeply challenge the political structures to which they are tied.”[265] Yet scientific communities are still an important site of meaning making and source of ideas. Haas argues that scientific communities have special influence under conditions of uncertainty, and when a crisis is recognized, they are the ones tasked with providing key information about interests, consequences, and solutions.[266] But sometimes, the information causes the crisis. The epistemic communities approach assigns scientists too much leeway in defining the meaning of scientific findings; Emanuel Adler and Haas describe the role of scientists in the “selection” of shared goals and dissemination of “their preferred world vision.”[267] This implies that scientists choose their consensus for its fit with the needs of policymakers in a crisis. But the emergence of problems like the ozone hole, ocean acidification, and space debris, which serve no obvious political interests and challenge existing ideas, suggest that this model may be overlooking something fundamental.

Two examples illustrate how ideas and interests are shaped by the material context. The NIEO movement and its associated ideas should be an easy case for constructivism, but in fact its influence on global commons regimes can be significantly explained in terms of geography, science, and technology. Most obviously, the G77’s strong bargaining position was significantly a result of high prices for globally traded commodities, which eventually collapsed. This situation resulted from the distribution of

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[265] Hampson and Reppy, *Earthly Goods*, 194.
[266] Haas, *Epistemic Communities, Constructivism, and International Environmental Politics*, 10.
[267] Emanuel Adler and Peter M. Haas, “Conclusion: Epistemic Communities, World Order, and the Creation of a Reflective Research Program,” *International Organization* 46, no. 01 (December 1992): 367.

natural resources and the development of new extraction technology.[268] The successes the G77 did achieve resulted in regime rules that mandated technology transfer, which "eliminates the advantage of states technically able to recover a resource."[269] The complexity and expense of relevant technology ensured its limited and asymmetrical distribution, thereby necessitating transfer for the achievement of NIEO goals. The overall historical wealth inequality that motivated the NIEO movement was also significantly a result of uneven technological access to non-terrestrial domains. Membership in the G77, their leverage in negotiations, the content of NIEO values, and their translation into regime mandates all illustrate the influence of geography and technology on GCRs.

Another important example is the ecological paradigm of management, which challenges "traditional policies for managing discrete activities or physical resource spaces."[270] Haas notes the existence of "holistic ecological beliefs," which emerged in the 1960s and 1970s and progressively influenced the construction of global environmental agreements.[271] The idea of universal ecological principles has been challenged for its supposed denial of the relevance and validity of local knowledge. This position implies that any scale of knowledge production or content is relevant, so long as it contains practices and ideas related to the environment. If the proposed solution is local, then the framing of the problem should be local.[272] These positions fail to register the important fact that ecosystems have a real, material existence that determines the relevant scale for

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[268] Ann L Hollick, *U.S. Foreign Policy and the Law of the Sea* (Princeton, N.J.: Princeton University Press, 1981), 350.
[269] Ibid., 380.
[270] Haas, *Epistemic Communities, Constructivism, and International Environmental Politics*, 174.
[271] Ibid., 17.
[272] Sheila. Jasanoff and Marybeth Long. Martello, *Earthly Politics: Local and Global in Environmental Governance* (Cambridge, Mass.: MIT Press, 2004), 4–5.

understanding causal relationships, defining problems, and formulating solutions. Coral bleaching occurs locally, but ocean warming may be regional and temperature rise is global. The problem may be experienced locally, but that does not mean a local definition is accurate or a local solution will be effective. Ecological principles emerged as guides for GCRs because scientists created and disseminated ideas, but scientists advanced these ideas because they had progressively uncovered the interconnections and dynamics of real material ecosystems.

The epistemic communities idea is compatible with materialist geopolitics, and together they tell a more complete story than either accounts for alone. Epistemic communities serve as a kind of intervening variable or translation mechanism between the material context and regimes, because they are the carriers of scientific knowledge. Such knowledge is impactful and important because it is scientific, not simply because it is carried and conveyed by scientists.

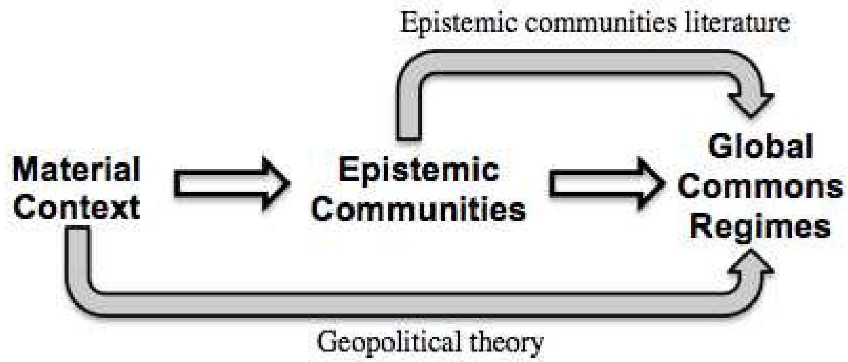

Figure 5 – Relationship between geopolitical theory and epistemic communities

Planetary Geopolitics

If international politics is conceived as a never-ending play with a complex plot, an analyst or critic could focus on the actors, the script, the set, or the meaning ascribed to the play by the audience. Planetary geopolitics considers the importance of the stage, and the constraints and possibilities it presents for the play of human activity.[273] Foregrounding the physical setting for human activity – the material context – illuminates basic structural influences on the practices, interests, and problems that motivate policy- and treaty-making. This section begins to unpack how those structural influences are identified and characterized in this project. After describing the general methodology for analyzing GCRs and their relationship to the physical environment, this section outlines two key propositions made by planetary geopolitics: regimes are often constructed without reference to major structural features of the material context, and regimes do not adjust well to changes in the material context. After defending these propositions, these ideas are connected to the idea of regime effectiveness in the subsequent section.

[273] Daniel Deudney and Elizabeth Mendenhall, "Green Earth: The Emergence of Planetary Civilization," in *New Earth Politics*, ed. Simon Nicholson and Sikina Jinnah (Cambridge, MA: MIT Press, 2016), 47.

Comparative Historical Analysis

The methodology of Comparative Historical Analysis (CHA) is applied to international management in two non-terrestrial spaces: the ocean and outer space.[274] Each case deals with complex outcomes on a very large scale, which can be best understood in light of several temporal processes, including the coalescence of scientific knowledge, the progression of technological capabilities, and the negotiation and implementation stages of global governance. The CHA methodology focuses on the generation of new theories that account for the structural features of international politics, in this case the structuration that results from institutions and individuals operating within the bounds of geographical, ecological, and technological possibility through time. The project addresses this set of variables as a coherent causal package – the 'material context' – that creates significant opportunities, challenges, and possibilities for international governance institutions with a given set of goals or purposes. Using two cases, provisional generalizations can be made about the causes of a particular outcome: the failure of GCRs to achieve their goals. Because each domain – the ocean and outer space – is examined across time, planetary-scale space, and multiple issue areas, comparative analysis can take place both within and across cases. The theory this project aims to extract and build from the empirical cases is complementary to existing theories, acknowledging the causal complexity surrounding global commons regimes.

The temporal orientation of CHA is well-suited to this effort to explain the dysfunctions, failures, and ineffectiveness of GCRs over time. Relative time frames for scientific knowledge accumulation, technological change, and regime building and implementation matter for the chances of effectiveness. The formation of scientific

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[274] James Mahoney and Kathleen Ann Thelen, *Advances in Comparative-Historical Analysis*, 2015, 3–4.

knowledge about coral bleaching, for example, will impact the ocean governance regime differently depending on whether scientific consensus formed before or after the core regime was negotiated. Tracing changes in the material context over time, and their influence on collective management institutions, draws on the existing literature about path dependence, feedbacks, critical junctures, and other patterns of institutional change.[275] The pace, trajectory, and timing of alterations in global commons regimes is shaped by in the pace, trajectory, and timing of scientific and technological change. Disentangling and synthesizing these connections help create a coherent theory of the effectiveness of global commons regimes in non-terrestrial planetary spaces.

Regime Pathology

GCRs are often pathological, in that their design inhibits their effectiveness over time. Regimes, or their components, are ineffective when their assumptions about the world diverge from what we actually know, and/or what is actually true. An inflexible regime is prone to be pathological because it will have decreasing congruence with scientific knowledge. When built on outdated science, and designed for old technology, inflexible regimes are unable to address contemporary sources and understandings of global environmental problems.

There are many reasons why regimes do not respond and adjust to new scientific knowledge about non-terrestrial spaces, and the origins of these inflexibilities are not explicitly explained by shifting material contexts and understandings of them. Planetary geopolitics focuses on the ways and reasons that non-adjustment dooms GCRs to ineffectiveness. The concepts of 'critical junctures' and 'path dependence' imply that there are specific moments when institutional adjustment is possible, but that institutions

[275] Ibid., 23–24.

are generally resistant to change. Critical junctures might include new scientific information or new technological capability in a non-terrestrial domain, which significantly alters understandings of possibilities and consequences. Relatively sudden discoveries or innovations can prompt a critical juncture, a period where actors' choices have an increased probability of influencing regime effectiveness.[276] When a choice is made – typically to ignore or downplay the significance of the new (or newly understood) material context – the phenomenon of 'path dependence' suggests that it becomes increasingly difficult to reverse. Each step in a particular direction institutionally makes it harder to turn back.[277] This phenomenon, whereby existing arrangements shape the pace and direction of institutional change, is especially likely in regime complexes, where multiple overlapping and non-hierarchical institutions characterize a single regime.[278] The resulting institutional lock-in makes regimes inflexible, inefficient, and ineffective.

Political Geography

Accounting for scientific knowledge and technological capability requires attentiveness to political geography, which is another potential source of dysfunction for GCRs. John Agnew and Luca Muscarà define political geography as "a set of scholarly and political ideas about the relationship of geography to politics," with roots in geography, political science, sociology, anthropology, and IR. Theories and descriptions in political geography all include geography and politics as the key variables, but which is the cause and and which the effect has shifted over time. Political geography as an area of inquiry originally focused on how geography influences politics, but contemporary

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[276] Giovanni Capoccia and R. Daniel Kelemen, "The Study of Critical Junctures: Theory, Narrative, and Counterfactuals in Historical Institutionalism," *World Politics* 59, no. 3 (April 2007): 341–69.
[277] Paul Pierson, "Increasing Returns, Path Dependence, and the Study of Politics," *The American Political Science Review* 94, no. 2 (267 251AD): June 2000.
[278] Kal Raustiala and David G. Victor, "The Regime Complex for Plant Genetic Resources," *International Organization* 58, no. 02 (April 2004): 279.

theorists are more interested in the ways that politics influences geography.[279] Agnew and Muscarà suggest in *Making Political Geography* that it is important to pursue a middle position, by theoretically balancing between determinism and social constructionism. This is reminiscent of Latour's 'hybrid objects,' part-ideational and part-material with no particular proportion or core. Instead of seeking a neutral balance, it is better to push farther in the direction of materialism, by illustrating the continued utility of research on how material geography (broadly construed) affects and influences international politics.

Agnew and Muscarà describe the approach of political geography as thinking in terms of the maps inherent in a political story. Maps are "the 'technology' or methodology most specific to geographical thinking."[280] They are a "graphic representation of the milieu," and a "form of symbolization with special utility for encoding and transmitting human knowledge of the environment."[281] Maps thus are summary descriptions of material contexts. Examples include spatial representations of coastlines, the seafloor, orbital pathways, atmospheric currents, and other natural material planetary dynamics and processes. As material observations are systematized, vernacularized, and diffused they place basic constraints on our mental images of what a domain is, what is happening there, and what is possible there. Maps create political places, because they represent "natural locations that have acquired a social and psychological significance insofar as they ground political outlooks and projects."[282] The 'global commons' designation is a kind of mental map, because it entails a global geographic frame and international

[279] John A. Agnew and Luca Muscarà, *Making Political Geography*, 2. ed (Lanham: Rowman & Littlefield, 2012).
[280] Ibid., 10.
[281] Arthur Howard Robinson and Barbara Bartz Petchenik, *The Nature of Maps: Essays toward Understanding Maps and Mapping* (Chicago: University of Chicago Press, 1976).
[282] Agnew and Muscarà, *Making Political Geography*, 177.

membership. Agnew and Muscarà argue "geographical scale is imposed on the world and not inherent to it," but the material dynamics of the ocean and outer space entail patterns and interconnections that have an intrinsic scale.[283] For example, ocean circulation is dominated by meso-scale eddies, a feature that was discovered, not constructed.[284] A geopolitical approach that focuses on the geography of the material context is not completely consistent with all of Agnew and Muscarà's premises and prescriptions, but it does pursue a research agenda that they promote: the planetary commons, global politics of the physical environment, and political geography of the environment.[285] Maps of the physical environment (including global technological systems) illustrate spatial patterns, and they help create and define political places like the planetary commons. These interactions and places are the objects of global governance.

Although it has a long historical legacy, planetary geopolitics can be understood as something new. Prompted by the dire realities of climate change, scholars are paying increasing attention to the central importance of scale for conceptualizing problems and organizing solutions. New tools of geospatial analysis, like geographic information systems (GIS), enable the visualization and analysis of multiscalar phenomena.[286] New problems and new technologies have prompted a (re)turn to the material context as a source of constraints, conditions, and opportunities for international politics. The next section outlines the relationship between the planetary material context and the successes and failures of global commons regimes.

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[283] Ibid., 201.
[284] Deborah Ann Glickson et al., eds., *Oceanography in 2025: Proceedings of a Workshop* (Washington, D.C: National Academies Press, 2009), 53.
[285] Agnew and Muscarà, *Making Political Geography*, 201, 11, 186.
[286] Kate O'Neill et al., "Methods and Global Environmental Governance," *Annual Review of Environment and Resources* 38, no. 1 (October 17, 2013): 462.

Regime Effectiveness

Defining and evaluating effectiveness is a difficult task, because each regime faces a different problem structure, utilizes different mechanisms to influence behavior, and confronts uncertainties about the causes and consequences of human activity. In other words, regimes differ in terms of what they confront, what they know, and what tools they are using. The lack of clear counter-factual scenarios means that analysis requires systematic inferences and the application of theoretical perspectives in order to judge regime effectiveness.[287] Nevertheless, a simple definition of regime effectiveness is possible: an effective regime achieves its goals and purposes by influencing actors to change their behavior in a way that solves problems and satisfies interests, especially shared problems and collective interests. This section surveys the literature on regime effectiveness, considering how it is defined and evaluated, and the conditions under which effectiveness is achieved.

Effectiveness Defined

Regime effectiveness requires causing changes in the behavior of relevant actors, especially those whose behavior causes collective problems.[288] What type of behavior is required, however, is a subject of contention among scholars. Oran Young identifies six dimensions of effectiveness, which can exist in multiple possible combinations: problem solving, goal attainment, behavioral change, process effectiveness (which includes compliance), constitutive effectiveness (effort), and evaluative effectiveness

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[287] Barrett, *Environment and Statecraft*, xi.

[288] O. R. Young and M.A. Levy, "The Effectiveness of International Environmental Regimes," in *The Effectiveness of International Environmental Regimes: Causal Connections and Behavioral Mechanisms*, ed. O.R. Young (Cambridge, MA: MIT Press, 1999), 20.

(performance).[289] Although each is slightly different, these standards can be grouped into two basic definitions of effectiveness: either regimes are effective when actor behavior conforms to regime dictates (behavior, process, constitutive, and evaluative), or they are effective when actor behavior achieves the substantive goals of a regime (behavior, problem solving, goal attainment). This section will assess and reject the former understanding of effectiveness, in favor of a notion of effectiveness that is more difficult to define and evaluate, but also more meaningful for determining whether a regime is 'working.'

Compliance is a straightforward measure of effectiveness, as the criteria for evaluation are directly implied by the rules and norms of the regime, which sometimes include institutions for assessing whether a given actor is in compliance. Compliance is therefore a regime-specific standard, in that it compares the actual behavior of relevant actors with the specific dictates and injunctions of the regime. Compliance includes Young's notion of process effectiveness, which requires members to incorporate regime provisions into their domestic legal and political systems.[290] It also captures constitutive effectiveness, which entails the expenditure of time, energy, and resources, and evaluative effectiveness, which is a measure of performance rather than consequences of a regime.[291] Compliance basically entails that members change their behavior in response to a regime, in order to fulfill its specific obligations.

The compliance standard can be understood as the relic of a bygone era in political science. In early debates within institutionalism, compliance was used to

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[289] Oran R. Young, "The Effectiveness of International Governance Systems," in *International Governance: Protecting the Environment in a Stateless Society* (Ithaca: Cornell University Press, 1994), 140–62.
[290] Ibid., 146.
[291] Ibid., 148–49.

demonstrate that international institutions had an appreciable effect on state behavior. Indeed, the behavioral approach to conceptualizing regimes relies on a minimum threshold of compliance to prove that a regime even exists. By conflating existence and effectiveness, these regime theories are incapable of conceiving an institution that exists but that actors do not comply with, a condition that intuitively holds for many historical regimes. States rarely negotiate and ratify treaties that would be difficult to comply with, or where their non-compliance would be visible, or trigger punitive measures. As a result, perfect compliance is often insufficient for solving collective problems, because regime provisions were never adequate in the first place.[292] Compliance is therefore a poor standard for evaluating whether existing regimes 'work.'

Another way to evaluate the effectiveness of regimes is to consider whether they have achieved their own (typically external) goals and purposes; has the regime solved the problem it was meant to solve, or achieved the collective benefit it was meant to achieve?[293] These goals may or may not be embedded within the regime as principles, which include "beliefs of…rectitude."[294] Whether or not they form part of the explicit content of GCRs, external goals and purposes motivate the negotiation and ratification of international treaties to manage non-terrestrial spaces. Although regime formation tends to be motivated by problem solving, actors typically frame this as the achievement of

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[292] Ibid., 147.
[293] Matthijs Hisschemoller and Joyeeta Gupta, "Problem-Solving through International Environmental Agreements: The Issue of Regime Effectiveness," *International Political Science Review* 20, no. 2 (1999): 151–74.; Young, "The Effectiveness of International Governance Systems," 143; Pamela S. Chasek, David Leonard Downie, and Janet Welsh Brown, *Global Environmental Politics*, Sixth edition, Dilemmas in World Politics (Boulder, Colorado: Westview Press, a member of the Perseus Books Group, 2014), 237; Peter M. Haas, Robert O. Keohane, and Marc A. Levy, eds., *Institutions for the Earth: Sources of Effective International Environmental Protection*, Global Environmental Accords Series (Cambridge, Mass: MIT Press, 1993), 7.
[294] Stephen D. Krasner, ed., *International Regimes*, 11. print, Cornell Studies in Political Economy (Ithaca, NY: Cornell Univ. Press, 2004), 2.

more general goals or values.[295] These more general values, such as ‘sustainability’ or ‘equity,’ represent important criteria of regime effectiveness, insofar as they reflect the reason a given regime is implemented and maintained.[296] If over-fishing continues to accelerate despite the global fisheries regime, we must describe the regime as ineffective even if all its specific injunctions were being satisfied. The exact character of these goals, and the assessments of whether or not they are being achieved, are (or should be) subject to revision and re-articulation in the face of scientific and technological advance. For example, the definitions of two commons regime goals – ‘sustainability’ and ‘equity’ – change with the material context. Whether these changes are accounted for by GCRs is critical for their effectiveness.

The concept of ‘sustainability’ implies balance between system maintenance and reproduction and the disruptions of external actors who exploit the system for various purposes. In this way, sustainability has no content without reference to a particular system. The system that needs to be sustained might be thought of as an economic system, whose level of resource extraction must be sustainable.[297] Or the system to be sustained may be thought of as an ecological one, subject to internal and external sources of disruption and flux.[298] In the case of the ocean, ecological and economic systems are intertwined by the concept of ‘resources.’ A sustainable regime, allows “as many of the highest priority uses as can be accommodated without harm to the resources

[295] Young, “The Effectiveness of International Governance Systems,” 151.
[296] Hasenclever, Mayer, and Rittberger, *Theories of International Regimes*, 2.
[297] William Ophuls, *Ecology and the Politics of Scarcity. Prologue to a Political Theory of the Steady State* (San Francisco: Freeman, 1977).
[298] Daniel B. Botkin, *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered, from Climate Change to Species Extinction, How Life Persists in an Ever-Changing World* (Oxford ; New York: Oxford University Press, 2012).

themselves."[299] This limit on sustainable use is defined materially and given precision by scientists. The limit of the atmosphere's 'global sink' resource is a function of its physical and chemical properties, which shift, attenuate, and concentrate toxins in different ways and to different degrees than, say, the ocean as a global sink. The goal of 'sustainable fishing' requires scientific knowledge of reproduction patterns, growth rates, and total numbers, evident in the notion of a 'maximum sustainable yield,' which is embedded within fisheries management institutions. Because the knowledge necessary to make assertions about sustainable use is often lacking, some regimes adopt a 'precautionary principle' designed to deal with scientific uncertainty.[300] The basic question of sustainability is: how much use is too much use, such that it decreases possible future use? The answer is different depending on the resource, so 'sustainability' as a regime principle does not function as a criterion for effectiveness without domain specific scientific knowledge.

The concept of 'equity' is entangled with science and technology. The principle of equity entails equality of access, benefit, or consequences. It often includes an historical element, insofar as many of the G77 countries argue that the imperialist predations of the past few centuries are responsible for their comparative lack of technological access to non-terrestrial domains. The 'common heritage' concept, first articulated by Arvid Pardo in 1967, is an application of the principle of equity to commons resources.[301] The principle has been applied to commons regimes in two basic

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[299] Brown et al., *Regimes for the Ocean, Outer Space, and Weather*, 88.
[300] Paul G. Harris, ed., *Routledge Handbook of Global Environmental Politics*, (London [u.a.]: Routledge, 2014), 132.
[301] Douglas M Johnston, *The Theory and History of Ocean Boundary-Making* (Kingston: McGill-Queen's University Press, 1988), 20; Sumit Majumdar, "Institutions for International Co-Operation: An Analysis of the United Nations Law of the Sea Conference and Convention," *Economic and Political Weekly* 25, no. 48/49 (December 1, 1990): 2684.

ways. Several regimes incorporate a mandate for transfer of technology from advanced to developing states in order to 'level the playing field' and rectify inequities in access, or share the means for alleviating a mutual vulnerability. Other regimes challenge pre-existing 'first come, first served' norms with a principle of equal claim despite (current) unequal access. These types of arrangements are associated with resources that require advanced technology to access, such as deep seabed minerals or geo-stationary orbit. As technology advances, its composition and distribution change, and so too do the conditions required for achieving domain-specific equity. Equity comes into play in a slightly different way regarding globally shared vulnerability to events like climate change, sea-level rise, and ocean acidification. The failure of a regime to achieve its more immediate purpose of, for example, mitigating sea-level rise, is framed as an equity issue because of the distribution of consequences when global commons are poorly managed. For example, the small island developing states are significantly more vulnerable to rising sea levels than the industrialized countries whose emissions are the primary cause of global warming. Even when a regime targets a global issue, concern about its failure to mitigate shared problems often is manifested in an argument about lack of equity.

Effectiveness Explained

The primary literature on regime effectiveness comes from neo-liberal institutionalism, which tends to elevate the importance of regime design. Theorists have identified a large number of obstacles to and conditions of regime effectiveness, which Young categorizes using two metrics. First is decision variables versus structural variables; decision variables are "subject to conscious control or manipulation" by regime designers and negotiators, whereas structural variables are "features of the larger physical, biological, or social environment" that are not subject to conscious control.[302] An additional metric concerns the location of the variable: is it endogenous, exogenous, or is there a linkage between the two? Endogenous variables come from regime design, whereas exogenous variables include a broad array of external conditions, especially associated with power, interests, and knowledge. Linkage variables consider "the fit between the institutional character of a governance system and the environment in which it is expected to function."[303]

The relationship between regimes and the material context spans all of these categories. It impacts decision-making and endogenous variables insofar as it is concerned with flexibility in regime design. Geopolitical variables – geography, ecology, and technology – can be understood as exogenous and structural. But the main focus is linkage: what is the relationship between regime design and the material context, and how does that relationship contribute to ineffectiveness? Because neo-liberal institutionalism is my main theoretical interlocutor, I will first review two endogenous explanations for effectiveness from this body of theory. Institutionalists tend to focus on the constellation of interests – how they are configured, and whether institutional arrangements can reconfigure them in a way that solves collective action problems.[304] For this reason, they are especially concerned with regime design.

Neo-liberal institutionalists focus on the structure of incentives as a key determinant of effectiveness. Cooperation is achieved not by changing the content of

[302] Young, "The Effectiveness of International Governance Systems," 152–53.
[303] Ibid., 153.
[304] Ibid., 157.

actors' interests, but by adjusting the incentives that drive their behavior.[305] There are many possible mechanisms for changing incentives, including monitoring and its reputational effects, capacity building and transfer, increasing levels of concern by raising awareness, and treaty-based inducements and punishments.[306] Because treaty design shapes actors' incentives, institutionalists often focus on achieving the best possible design. The ideal regime alters incentives in a way that makes its rules and norms "self-enforcing," because compliance is individually rational, collectively rational, and perceived as legitimate.[307] Restructuring incentives only works in cases where common interests or mutual benefit are achievable through cooperation, because these situations contain an alternative incentive structure that motivates collective action.[308]

In the case of regulatory regimes, enforcement is often understood as a critical means of re-aligning incentive structures, because members have incentives to cheat.[309] Levels of enforcement depend on the capacity (time, energy, and resources) available and devoted to enforcing the rules and norms of a given regime. Capacity is understood as a necessary condition for effectiveness.[310] Enforcement requires identification of rule-breakers (monitoring and verification), and may include formal adjudication and punishment. Effectiveness is therefore partially a function of "the strength of the key control provisions…but also the provisions on reporting, monitoring, regime

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305 Hasenclever, Mayer, and Rittberger, "Interests, Power, Knowledge," 185.; Barrett, *Environment and Statecraft*, xv.
306 Peter M. Haas, Robert Owen Keohane, and Marc A. Levy, eds., *Institutions for the Earth: Sources of Effective International Environmental Protection*, 4. printing, Global Environmental Accords Series (Cambridge, Mass: MIT Press, 2001), 398.; Barrett, *Environment and Statecraft*, xv.
307 Barrett, *Environment and Statecraft*.
308 Hasenclever, Mayer, and Rittberger, "Interests, Power, Knowledge," 184, 186.
309 Oran Young, "Is Enforcement the Achilles' Heel of International Regimes?," in *Governance in World Affairs* (Ithaca, NY: Cornell University Press, 1999), 83–84.
310 Chasek, Downie, and Brown, *Global Environmental Politics*, 238.

strengthening, noncompliance, and financial and technical assistance."[311] Typically a focus on enforcement is associated with the compliance view of effectiveness.[312] Because capacity problems are widespread, lack of enforcement provides an easy explanation for ineffectiveness.[313] Compliance can be enhanced by building up domestic and secretariat capacity, increasing assistance to other members, improving monitoring and reporting, and considering sanctions, among other things.

Geopolitical Conditions of Effectiveness

The conditions of effectiveness identified by neo-liberal institutionalists tend to assume that interests and problems are well formed and well understood, and can therefore be pursued straightforwardly by altering incentives for behavior. But the geopolitical approach argues that this situation, which serves as a pre-requisite for successful regime design, cannot be assumed. When interests and problems are obscure, inchoate, or poorly understood by regime designers, the resulting institutional forms are unlikely to alter behaviors in a way that achieves desired outcomes.

The basic argument of the geopolitical theory of GCRs is that *regimes are effective insofar as they demonstrate a fit or match with the material context*. The idea of 'isomorphism' represents the ideal or perfect match. But because the material context itself, and our scientific image of it, changes over time, maintaining institutional isomorphism with the structure of the environment (both natural and technological) is a challenging set of tasks. The ideal regime is functional, meaning that it is directed at achieving a specific external outcome, which it does in fact achieve. The material context constrains which regime designs will be functional, but the choice of regime design is a

[311] Ibid., 237.
[312] Young, "Is Enforcement the Achilles' Heel of International Regimes?," 80.
[313] Ibid., 96.

social and political question.[314] For regimes to function, they must consistently obtain and rely upon the best possible understanding of the material situation, which in the case of non-terrestrial domains happens to be provided by Earth system sciences. Institutionalists already recognize the value of consensus; Young says "a regime is likely to be effective…when it rests on a common conception of the problem to be solved and some degree of consensus regarding what is needed to fashion a solution."[315] The geopolitical approach adds another condition: the consensus on which regimes are built must be scientifically valid and credible. Most institutionalists suggest that effectiveness requires regimes to account for the "nature of the underlying problem" or "characteristics of the issue area," such as biophysical properties, spatial and temporal scales, and the availability of scientific knowledge to characterize them.[316] In order for a GCR to be effective, it must be attentive to the resolution and detail of the non-terrestrial material domain it seeks to govern, especially as it changes over time.

The geopolitical theory of GCRs outlines two conditions of effectiveness: the acquisition of necessary scientific knowledge of the material context, and the institutional flexibility to respond and adapt to new information about interests and problems. These conditions are briefly surveyed here, examined throughout the case chapters, and revisited in the conclusion.

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[314] Deudney, *Bounding Power*, 59.
[315] Young, "The Effectiveness of International Governance Systems," 157.
[316] Barrett, *Environment and Statecraft*, xii; Vogler, *The Global Commons*, 177; Eric Brousseau et al., eds., *Global Environmental Commons: Analytical and Political Challenges in Building Governance Mechanisms* (Oxford University Press, 2012).

Acquisition of necessary information

The role of science in creating effective environmental regimes is both contested and underdeveloped.[317] But scientific knowledge is critical to regime effectiveness, because it reveals interests and characterizes problems, although these are not always recognized, acknowledged, or acted upon. The goals and purposes of regimes – what makes them functional – are comprised of interests to be satisfied and problems to be solved. But defining the precise 'functions,' and designing institutions to fulfill them, requires careful planning and analysis. Scientific knowledge about relationships of cause and consequence informs risk assessment, cost-benefit analysis, and stakeholder identification.[318] An institution 'fits' with the material context when it reflects contemporary scientific consensus about planetary systems. According to Young, ecosystem properties relevant to institutional fit include structures (complexity, homogeneity, interdependence), processes (productivity, growth, stabilization, change), and linkages (boundary conditions, transboundary interactions).[319] Geography and technology are also part of the material background with which regimes ought to fit. Knowledge about shared consequences is especially influential for regime formation, and substantially explains which problems are addressed and when.[320] A "shared perception of mutual vulnerability" presents a clear and collective interest, which can be pursued through institutional cooperation.[321] But building a functional regime is not easy or inevitable, because scientific study of complex planetary systems remains plagued by data deficiency and uncertainty. Lack of scientific guidance presents risks for

[317] Lidskog and Sundqvist, "The Role of Science in Environmental Regimes: The Case of LRTAP," 94.
[318] Radoslav S. Dimitrov, "Knowledge, Power, and Interests in Environmental Regime Formation," *International Studies Quarterly* 47, no. 1 (March 2003): 123–50.
[319] Oran R Young, *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale* (Cambridge, Mass.: MIT Press, 2002), 64.
[320] Dimitrov, "Knowledge, Power, and Interests in Environmental Regime Formation," 124.
[321] Vogler, *The Global Commons*, 224.

effectiveness, because "causes, impacts, consequences, and solutions are often interconnected in surprising ways."[322] If a regime is built without knowing the relationship between means and ends, it is unlikely to achieve its particular ends.

Because perfect information – in the form of universal, comprehensive scientific knowledge – is illusory, effective regimes must have a functional relationship with uncertainty. In other words, regimes should be designed in a way that acknowledges what negotiators and bureaucrats (informed by scientists) do not know, and what they need to know. Young cautions that "simple ignorance about the behavior of biotic and abiotic systems" is a real and important source of poorly designed regimes.[323] Complex problems like ocean acidification and space debris require significant scientific investment, in order to identify their scale, intensity, and time frame. Uncertainty can cause public goods to be under-valued relative to parochial interests. Long-term consequences are virtually ignored if threats are poorly defined, and as a result public concern is very low.[324] Because environmental experts do not themselves create regimes, uncertainty is easily overlooked. A dysfunctional relationship with uncertainty will be described in the section on specific regime pathologies.

Institutional flexibility

Regimes are "articulated at particular points in time," so there is a risk that they will "codify existing knowledge in rules that are difficult to change."[325] Because the material context changes over time, in both reality and image, Young argues that effective regimes must periodically "review the relationship between ecosystem

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[322] Chasek, Downie, and Brown, *Global Environmental Politics*, 251.
[323] Young, *The Institutional Dimensions of Environmental Change*, 67.
[324] Chasek, Downie, and Brown, *Global Environmental Politics*, 249–50.
[325] Young, "Is Enforcement the Achilles' Heel of International Regimes?," 102; Haas, Keohane, and Levy, *Institutions for the Earth*, 2001, 411.

boundaries and regime boundaries."[326] This same process must also occur with geographical and technological geographies; as maps of dynamic planetary systems and changing human activities change, so too must the regime. Biophysical systems in particular "are characterized by processes of evolution that tend to be nonlinear, subject to abrupt changes, and irreversible."[327] The more rapidly and profoundly scientific understanding changes, typically from uncertainty to certainty, the more important the need for institutional flexibility becomes.[328] In this situation, the effectiveness of a "brittle" regime, or one firmly constructed on outdated and inaccurate premises, will be short lived.[329] This is because material contextual change typically means an alteration in the problem itself, and scientific knowledge accumulation updates and refines our understanding of shared problems.[330] A primary condition of regime effectiveness over time is therefore the built-in capacity for a regime to adjust and adapt to new material situations, referred to as 'regime flexibility.'[331]

Regime Pathologies

The methodology of Comparative Historical Analysis distinguishes causal associations from incidental correlations by identifying particular mechanisms – or vectors of influence – through which a set of variables affects or influences outcomes. This project posits the existence of three types of regime pathology, and then investigates whether they exist in the case of the ocean and outer space, and how they affect the outcome of regime ineffectiveness. Regime pathologies are *institutional design features*

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[326] Young, *The Institutional Dimensions of Environmental Change*, 64.
[327] Brousseau et al., *Global Environmental Commons*, 6–7.
[328] Young, "The Effectiveness of International Governance Systems," 159.
[329] Ibid., 150.
[330] Ibid., 143.
[331] Ibid., 68.

that reinforce mismatches and misalignments between the material context and the regime. They are self-subverting features of regime design. Such regimes are guaranteed to be dysfunctional, and therefore ineffective, to the degree that they embody these pathologies. Although there are other causes of GCR ineffectiveness, the identification of three new mechanisms represents a contribution to theory development, specifically a geopolitical theory of regimes in non-terrestrial spaces. These pathologies will be outlined below, fleshed out in the case chapters, and re-visited in the conclusion.

Territorialization

In non-terrestrial planetary spaces, achieving regime goals and purposes requires getting the scale right: decision-making communities must include all those affected, and accountability mechanisms must apply to all those who are part of the cause.[332] In other words, institutional mechanisms must align with the geographies of cause and consequence. This insight about the appropriate scale of governance is over 40 years old: Seyom Brown and Larry Fabian noted in 1975 that in non-terrestrial realms, access and exploitation have "increasingly universal impacts, thereby widening the arena of necessary mutual accountability to include more and more of the human community, and thereby enlarging the necessity for correspondingly inclusive decision structures."[333] Yet the ocean and outer space regimes have, to a significant degree, inscribed a political geography of territorialization. Carving out territorial ownership and jurisdiction– whether they are attached to a geographical location (zones) or technology of access (flags) – conflicts with the material geography of non-terrestrial spaces. But because territorialization and nationalization entail rights and claims over valuable resources, this

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[332] Brousseau et al., "Introduction," 2.

[333] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 886.

political geography becomes rapidly and deeply embedded into our shared conception of these domains. The territorialization strategy for collective management has been extremely prevalent, but is “basically retrogressive” in terms of creating a functional relationship between “the evolving material world and the traditional international political system.”[334] Territorial political geography creates a durable mismatch between regimes and the geography of practices, problems, and interests.

Naturalization of Technology

Technology significantly determines which practices of access and exploitation are exercised in the ocean and outer space, and thereby plays a central role in defining the interests and creating the problems that motivate regime formation. Technology is also an important source of solutions, in that it can increase use efficiency (and decrease negative externalities), provide opportunities for monitoring and verification, and improve equity through its transfer and diffusion. Regimes therefore tend to contain specific injunctions regarding technology, especially its deployment (prohibition or mandate) and regulation (how, when, and by who it can be used by). But because technology changes over time through improvement and innovation, the problems and interests it creates, and the solution sets it provides, also change. A static or stagnant regime with regard to technology misses new requirements for effectiveness, and opportunities for its achievement through the control and use of technology. If regimes do not take account of the frontiers of technological research and development, a significant and dangerous lag will emerge between the assumptions about technology made by the regime, and its

[334] Ibid., 880.

actual impact on non-terrestrial spaces.[335] Regime dictates regarding specific technology naturalize a level of capability, and ensure a future mismatch between regimes and domain-specific practices, problems, and interests.

Frozen Ontology

Scientific knowledge has a "pervasive influence" on governmental decision-making and policy formation, because it is used for risk assessment and to calculate costs and benefits.[336] The perceptions of policymakers and negotiators "closely reflect the state of existing scientific knowledge."[337] This knowledge is used to define the nature of shared problems, which informs the construction of regime goals and the specific behavioral changes required to achieve them.[338] It is also used "to define the interests that political actors articulate and defend," whether parochial or collective.[339] In situations of scientific uncertainty, value judgments and interpretive contests often fill the gap.[340] But of course, the level of scientific uncertainty changes, scientific knowledge accumulates over time, scientific theories change, and scientific uncertainty decreases. The result is an identification of new problems and interests, and better understanding of the nature of cause, consequence, and solutions for previously recognized problems and interests. The threats of asteroid collision, cascading space debris, and ocean acidification were all discovered after the solidification of their associated governance regime, as well as new interests like marine genetic resources and asteroid mining. Scientific knowledge

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[335] Lynton Keith Caldwell, *Between Two Worlds: Science, the Environmental Movement, and Policy Choice* (New York: Cambridge University Press, 1992), 89.
[336] Clark A. Miller and Paul N. Edwards, eds., *Changing the Atmosphere: Expert Knowledge and Environmental Governance*, (Cambridge, Mass: MIT Press, 2001), 14.
[337] Dimitrov, "Knowledge, Power, and Interests in Environmental Regime Formation," 140.
[338] Ronald B. Mitchell, "Problem Structure, Institutional Design, and the Relative Effectiveness of International Environmental Agreements," *Global Environmental Politics* 6, no. 3 (August 2006): 77.
[339] Peter M. Haas, *Saving the Mediterranean: The Politics of International Environmental Cooperation*, (New York: Columbia University Press, 1990), 11.
[340] Brousseau et al., "Introduction."

accumulation has also "enlarged the depth of environmental problems by creating lengthy chains of environmental causality."[341] It has identified new global public goods, like ecosystem services, and redefined the terms of sustainable exploitation. But regimes tend to embed a particular understanding of the domain to be managed, which prevents adjustment to new conceptions of interests and problems.

Regimes are pathological when they are constructed in a way that ignores or under-emphasizes existing scientific uncertainty and inevitable scientific knowledge accumulation. This occurs as a kind of freezing the image of the governance domain, embedding within institutions the assumption that current maps and theories are already accurate, and will not change. This feature of regime design is understood as a virtue at least one STS scholar. Steve Rayner argues that ignorance is a "necessary social achievement" as opposed to a dysfunction, because it is "essential to maintain the organizational arrangements of societies."[342] New knowledge may be "uncomfortable" insofar as it reveals disagreements about facts or values, and risks causing "delicate institutional arrangements to fracture."[343] Rayner therefore recommends "information management strategies" that deny, dismiss, divert, or displace new information if it threatens the stability of existing institutional architectures. This form of 'leaning in' to ignorance assumes that regime durability, not effectiveness, is the ultimate goal. Rayner's proposal is a plan *for* regime pathology. If pursued, it would guarantee a growing

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[341] Ann Hironaka, "Science and the Environment," in *Science in the Modern World Polity: Institutionalization and Globalization*, ed. Gili S. Drori et al. (Stanford, Calif: Stanford University Press, 2003), 250.
[342] Steve Rayner, "Uncomfortable Knowledge: The Social Construction of Ignorance in Science and Environmental Policy Discourses," *Economy and Society* 41, no. 1 (February 2012): 108.
[343] Ibid., 13.

mismatch between the regime and material realities, thus guaranteeing steadily growing ineffectiveness.

Conclusion

This chapter has situated the project in the larger theoretical literatures that address science, regimes, and global environmental governance. In the next several chapters, the methodology of Comparative Historical Analysis will be applied to the historical cases of ocean and outer space governance, in order to evaluate the conditions of effectiveness and regime pathologies described above. The conclusion will return to these hypothesized mechanisms and features of (hypothetical) effective regimes for managing non-terrestrial spaces. The intention is to provide a constructive contribution to regime theory in IR, and also prescriptions for practitioners (diplomats and policymakers) attempting to redress existing and pervasive flaws in global commons regimes.

World Ocean: Maritime Expansion, Cartography, and Order Building

The Earth is an ocean planet, although it is more frequently understood as a terrestrial planet with multiple oceans. A contiguous body of salt water, the ocean covers 71 percent of the Earth's surface and surrounds the continental crusts that contain most of human civilization. The volume of oceanic space is staggering, accounting for 97 percent of the Earth's water and with an average depth over 2 miles. All this watery space comprises 99 percent of the Earth's biosphere, and contains variegated and complex ecosystems. Through energy and molecule exchange, the ocean and atmosphere are connected along the permeable border that is the sea surface. Through this connection, the ocean affects both weather and climate. The 'global ocean conveyor belt' circulates massive amounts of water on the timescale of millennia, and is a central component of nutrient and carbon dioxide cycles. But very little of what is now known about the ocean was known before the 20th century. Despite the grand scale of the ocean and its processes, the hydrosphere has occupied a central role in human history only in the last several centuries.[344]

For most of human history, direct access to the expansive ocean was extremely limited by its vast size and unfathomed depths. Coastal areas were first used regularly for food. Archaeologists believe that early humans survived climate fluctuations by

[344] Peter Benchley and Judith Gradwohl, *Ocean Planet: Writings and Images of the Sea* (New York: H.N. Abrams, Inc. and the Times Mirror Magazines, Inc. in association with the Smithsonian Institution, 1995); Darlene Trew Crist, Gail Scowcroft, and James M. Harding, *World Ocean Census: A Global Survey of Marine Life* (Richmond Hill, Ont. ; Buffalo, New York: Firefly Books, 2009).

clustering in high protein coastal zones.[345] As boat technology advanced, local and regional scale maritime communities emerged. These seafaring societies and networks were globally disconnected for many centuries, and each ocean world was defined by the culture and custom of its regional users.[346] Daniel Headrick identifies five great sea-faring traditions (Polynesian, Indian, Chinese, Mediterranean, and Western European) that brought humans out onto the ocean.[347] Through the activities of these groups and others, several major regional trading networks emerged and ebbed over the centuries.[348] When these networks became interconnected and globalized in the 'Age of Expansion' (15^{th} to 17^{th} century), the resulting density of actors and interests produced new norms and principles of international ocean law.

This chapter begins by comparing historical maritime activity in Polynesia, the Indian Ocean, and European waters, in order to demonstrate the diversity of possible ways of relating to the ocean and organizing seafaring activity. Because it was the European maritime states that collectively formed the foundations of the modern ocean governance regime (although not always consciously or cooperatively), their history will be unpacked in greater detail to set the stage for analysis. The second section describes the directed process of discovering the ocean undertaken by European maritime states, through which they collected, synthesized, and selectively disseminated geographic information. Although initially motivated by the quest for political and economic

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345 Curtis W. Marean, "When the Sea Saved Humanity," *Scientific American*, August 2010.; Jon M. Erlandson and Torben C. Rick, "Archaeology, Marine Ecology, and Human Impacts on Marine Environments," in *Human Impacts on Ancient Marine Ecosystems: A Global Perspective* (University of California Press, 2008).
346 Lincoln P. Paine, *The Sea and Civilization: A Maritime History of the World*, First Edition (New York: Knopf, 2013).
347 Daniel R Headrick, *Power over Peoples: Technology, Environments, and Western Imperialism, 1400 to the Present* (Princeton, N.J.: Princeton University Press, 2010), 11–20.
348 Philip E Steinberg, *The Social Construction of the Ocean* (Cambridge; New York: Cambridge University Press, 2001).

advantage, data collection eventually served the emerging disciplines of modern science. The third section examines three features of the ocean governance regime constructed during the early modern and modern eras, and considers their relationship with the evolving geophysical and technological realities of seafaring.

Polynesia

The Austronesian people used open, double-hulled and outrigger canoes to colonize islands across a full one-third of the global ocean, from Madagascar to what is commonly described as Melanesia, Micronesia, and Polynesia. Although the exact timeline of expansion is unknown, the last major wave of settlement in Oceania is

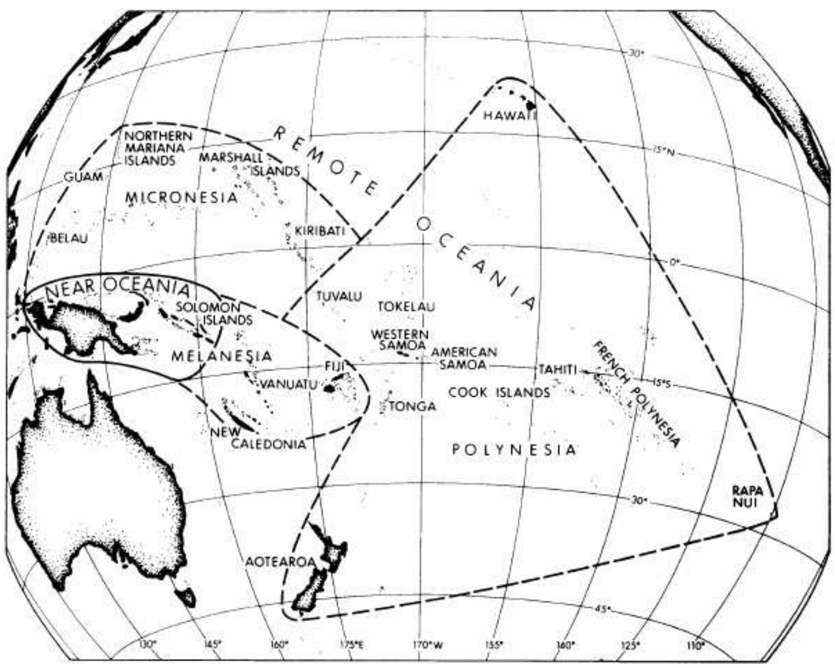

FIGURE I. Oceania, showing the conventional geographical division into Melanesia, Micronesia, and Polynesia, and the more prehistorically significant division into Near Oceania and Remote Oceania.

Figure 6 - Near and Remote Oceania, From Finney, "The Other One-Third of the Globe," page 275

thought to have ended around 1000 CE.[349] Austronesia navigation methods were advanced and ingenious, and relied on observations of the stars, sun, ocean swells, birds, and cloud formations.[350] Although their "craft and skill was limited to the tropics," they ranged widely on well-known ocean pathways, and out into unexplored parts of the ocean.[351] The Austronesians lived in a world covered by water, in which there were many islands. This worldview, and other social and resource pressures, encouraged Austronesian seafarers to explore and colonize the islands of what is best described as Remote Oceania.[352] In the hierarchal Polynesian societies, knowledge of routes was privatized and kept as a secret of navigator elites.[353] These sea-faring societies remained largely isolated from other maritime trading networks until the European Age of Expansion. Although Europeans began traversing Remote Oceania in 1520, they initially had neither the technological capability nor the interest to explore and colonize the vast Pacific. But by the late 18th century, the British and French began sending regular scientific and strategic expeditions to the Pacific, enabled by "vastly improved ships, navigation methods, and provisioning."[354] During the 19th century, many Polynesian archipelagos were annexed and colonized by European powers.

Indian Ocean

The Indian Ocean trading network thrived between 500-1500 CE, and connected diverse societies from Africa, Arabia, India, and Southeast Asia. The Indian Ocean offered a fortuitous geography for maritime trade, with high visibility, low currents, and regular alternation of winds. By the 13th century, navigation in the Indian Ocean was

349 Paine, *The Sea and Civilization*, 16.
350 Ben Finney, "The Other One-Third of the Globe," *Journal of World History* 5, no. 2 (Fall 1994): 280.
351 Headrick, *Power over Peoples*, 12.
352 Finney, "The Other One-Third of the Globe," 274.
353 Steinberg, *The Social Construction of the Ocean*, 59.
354 Finney, "The Other One-Third of the Globe," 287.

assisted by the use of magnetic compasses, North Star navigation, and sailing manuals. Although Indian Ocean ports were bustling entrepôts during this period, the ocean itself was understood as "a special space of trade, external to society."[355] Inland agriculture was a key source of wealth for rulers on the sub-continent, and coastal societies "did not seek to claim or organize the sea as a means for generating economic wealth."[356] There were few attempts to project maritime power, monopolize trade or routes, or colonize distant lands in the Indian Ocean. The maritime Melaka Code, formulated around the late 13th century and codified in the late 15th century, was the "prevailing maritime legal tradition for Southeast Asia."[357] The code was a series of laws for ships and shipping, as opposed to a law of the sea itself. The ship was the locus of jurisdiction in the code, and treated as a "territorial annex of its home state…a state-like territory."[358] Analogies within the Code compare the ship to a kind of "floating state." Although the Melaka Code did not persist and expand to cover global ocean activities, later international law reflects this basic approach to maritime governance.

China was, for a time, a powerful player in this trading network. China had been a relative latecomer Indian Ocean trade, but by the 14th century boasted "by far the largest navy and merchant marine in the world."[359] In the 15th century, China sent seven fleets across the Indian Ocean, concluding treaties of tribute and trade, and sometimes over-throwing local leaders. At this time, Chinese navigation was far ahead of the rest of the world, and Chinese captains could have sailed to America and around the world. But a confluence of domestic factors caused them to relinquish oceanic and regional sea faring

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[355] Steinberg, *The Social Construction of the Ocean*, 45.
[356] Ibid., 47.
[357] Paine, *The Sea and Civilization*, 366.
[358] Steinberg, *The Social Construction of the Ocean*, 51.
[359] Headrick, *Power over Peoples*, 15.

in the 15th century.[360] Chinese withdrawal from regional trading networks created an opportunity for new entrants to the Indian Ocean trading networks. The decline of Chinese regional sea power coincided with the arrival of European ships in the Indian Ocean.

Europe

The history of European seafaring in the early modern period would have lasting and international import, because it was the European tradition of maritime norms and laws that became globalized in the modern period. The rise of European maritime powers, and their jockeying for strategic and economic advantage, produced new motivations for establishing shared understandings about rights and duties in the world ocean. Mercantilist maritime states sought to accumulate wealth by controlling trade routes, and achieving preferential trade balances. The international law of the sea they produced and exported was not the result of cooperative planning, but the outcome of practical problem-solving, geopolitical tension, and merging maritime traditions.

European seafaring was divided into two separate spheres – the southern and northern – until the middle of the 13th century. In the Mediterranean, relatively simple coastal navigation facilitated regular maritime trade since the time of the Romans. In the North and Baltic Seas, fog and storms made navigation more difficult, but the colder seas contained especially productive fisheries. [361] European maritime powers waxed and waned, and a large number of polities shaped the prevailing systems of trade and power projection. These included the Hanseatic League, Scandinavia, the Dutch Republic, Venice, Genoa, the Ottoman Empire, England, France, Portugal, and Spain, among

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[360] Ibid., 16–17.
[361] Steinberg, *The Social Construction of the Ocean*, 68-70.

others. In the medieval period there were no common supra-territorial maritime laws, but codes of conduct developed between groups involved in shipping. In northern Europe, maritime regulations were often forged and enforced on the scale of towns. Several polities made claims to dominion over proximate seas, including the Venetians in the Adriatic Sea, the Genoese in the Ligurian Sea, and various Scandinavian countries in the Baltic Sea.[362] Northern and southern trading networks began establishing links in the 14th century, through both coastal and riparian navigation. In the 15th century, the emergence of mercantilism fueled competition between northern and southern European powers for control over increasingly global maritime trade routes.[363]

During the 'Age of Expansion' in the 15th through 17th centuries, the Portuguese and Spanish, and then the English and Dutch, successfully expanded trading networks and established colonies throughout the Atlantic and Indian Oceans.[364] Two technological advances facilitated the European globalization of maritime trading networks: southern Europeans excelled at map-making, and northern Europeans developed sophisticated navigation techniques. These advances combined with improvements in shipbuilding and innovations in ship financing, administration, and armament.[365] The newfound technological capability of global seafaring created a wealth of economic and political opportunities, and increasingly detailed and accurate maps facilitated the expansion of trading networks, colonies, and naval bases. The following sections will outline the history of European maritime activities in the 'Age of Expansion,' focusing on the

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[362] Thomas Wemyss Fulton, *The Sovereignty of the Sea: An Historical Account of the Claims of England to the Dominion of the British Seas, and of the Evolution of the Territorial Waters, with Special Reference to the Rights of Fishing and the Naval Salute* (Millwood, N.Y.: Kraus Reprint Co., 1976), 3–4.
[363] Steinberg, *The Social Construction of the Ocean*, 71.
[364] Paine, *The Sea and Civilization*, 406.
[365] Ibid., 429.

importance of cartographic information. The history of formal and customary international maritime law during this period will be examined in the second half of the chapter.

Portuguese

The northern and southern European nautical traditions first merged in Portugal, whose geographic location sits "at the intersection of the Mediterranean and North Atlantic seafaring systems."[366] The Portuguese caravel, which "opened the oceans to exploration," was a "hybrid, combining the best features of both the Mediterranean and North Atlantic ships."[367] In the early 15th century, the son of the Portuguese king, Dom Henrique 'the Navigator,' funded oceanic exploration from his villa on the southwestern point of the Iberian Peninsula. While some accounts suggest that Henrique founded a school for the study and teaching of navigation, historians have concluded that the famed center in Sagres never existed.[368] But Henrique did sponsor a series of expeditions down the western coast of Africa, motivated by both a missionary zeal and search for commercial advantage. He gave careful instructions to his captains about the systematic collection of data pertaining to coastal geography, navigation, trade goods and prices, and local languages.[369] The accumulated information was treated as a state secret, and housed in a 'hydrographical repository' tasked with issuing maps and collecting them upon return. The penalty for pilots giving or selling charts to foreigners was death. Non-Portuguese who did acquire Portuguese maps during this period often suspected

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366 Headrick, *Power over Peoples*, 20.
367 Ibid., 22–23.
368 W. G. L. Randles, "The Alleged Nautical School Founded in the Fifteenth Century at Sagres by Prince Henry of Portugal, Called the 'Navigator,'" *Imago Mundi* 45, no. 1 (January 1993): 20–28.
369 Paine, *The Sea and Civilization*, 387.

deliberate falsification of information.[370] Eventually the Portuguese rounded the tip of Africa and entered the Indian Ocean trade, where they established fortified outposts. Portuguese merchants dominated Indo-European maritime trade for a century, in large part "because the Portuguese controlled the maps."[371]

Spanish

Portugal and Spain dominated exploration and long-distance trade during the same period, the first century of the Age of Expansion. Spanish exploration focused on westward movement across the Atlantic, starting with the sponsorship of the Genoese Christopher Columbus's expedition. Although Columbus was searching for a westward route to Asia, he massively miscalculated the distance to China and Japan. This miscalculation resulted from an underestimation of the size of the Earth, in addition to bad information about the location of Japan. Unlike 'Terra Australis,' the hypothesized southern continent that 'balanced' Eurasia, "the possibility of an intervening continent was not even considered."[372] Ten years after Columbus returned from the Americas, Spain established the Casa de la Contratación in order to coordinate resource extraction and colonization of the newly discovered continent. One function of the Casa was to maintain a 'master chart' with up-to-date geographical information, and issue it only to those authorized by the Spanish crown. In 1524, Spain created the Council of the Indies to centralize administration of the growing Spanish empire. Spain initially maintained control of new territories through close control of navigational and geographic information. Domestically, the topic of who could sell which maps to whom was a

[370] J.B. Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," *Imago Mundi* 40 (1988): 61.
[371] Miles Harvey, *The Island of Lost Maps: A True Story of Cartographic Crime* (Random House, 2000), xii.
[372] Paine, *The Sea and Civilization*, 393.

subject of legal contention, and publications with geographic information were regularly censored. Over time, enough information was stolen or collected by explorers from other countries, and “the Spanish were reduced to defending their territorial claims by force of arms rather than by geographical secrecy.”[373]

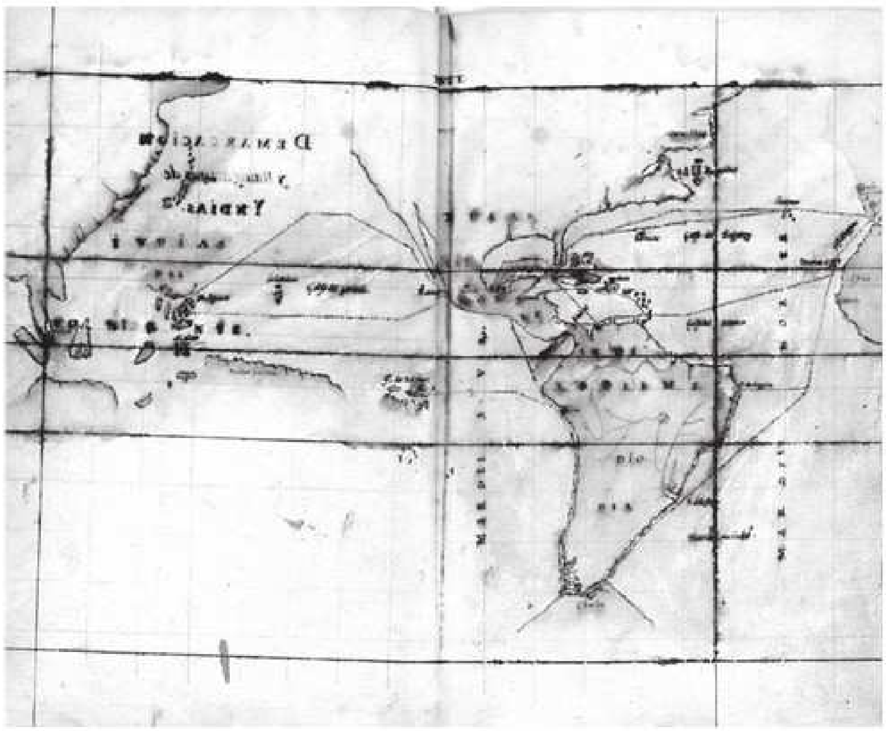

Figure 7.2 This map was the result of information gathered at the Council of the Indies. It is an “empty” map with only some geographical characteristics because that was the kind of information gathered at the Spanish centers of information. Map of the New World in Juan López de Velasco, *Descripción y división de las Yndias* manuscript, one map (manuscript, *c.* 1575). Reproduced courtesy of the John Carter Brown Library at Brown University.

Figure 7 - Council of the Indies Map, From Delbourgo, James, Nicholas Dew, History of Science Society, and Meeting. Science and Empire in the Atlantic World. New York: Routledge, 2008. pg 187

Dutch

When the Dutch Republic replaced Portugal as the dominant European power in the Indian Ocean, it was also with the aid of carefully guarded cartographic information. In preparation for establishing a vast Indian Ocean trading network, the Dutch East India

[373] James Delbourgo et al., *Science and Empire in the Atlantic World* (New York: Routledge, 2008), 38.

Company compiled a 'Secret Atlas' from 180 navigational charts, which had "the status of a state secret."[374] The Secret Atlas also contained "topographic views, maps and descriptions of Asian towns and coastlines."[375] It was compiled and distributed through the company's Hydrographic Office in Amsterdam, which paralleled Spain's Casa de la Contratación.[376]

Conflict with the Portuguese in the Indian Ocean began in the early 1600s.[377] The Dutch East India Company, established in 1602, ejected the Portuguese from the lucrative Spice Islands in 1605. After setting up an administrative headquarters in Batavia (modern Jakarta) in 1618, the Dutch quickly began creating new trading opportunities for themselves. In 1624 they built Zeelandia castle on Taiwan, which served as an entrepôt for trade with China, Japan, and the Philippines for several decades. Their success in replacing the Portuguese is partially explained by the Dutch adoption of a more modest and humble approach to relations with local rulers. After the Portuguese were banned from Japan in 1639, the Dutch East India Company secured exclusive access to trade in Japan, including precious Japanese silver, gold, and copper.[378] After their position in the Indian Ocean was assured, the Dutch turned their attention to the Coromandel Coast of India, where they set up lucrative textile factories. A separate Hydrographic Office was

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[374] Harvey, *The Island of Lost Maps: A True Story of Cartographic Crime*, xv.
[375] Gūnter Schilder, "Organization and Evolution of the Dutch East India Company's Hydrographic Office in the Seventeenth Century," *Imago Mundi* 8 (1976): 61–78.
[376] Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," 62.
[377] Around the same time, the Dutch were challenging the Portuguese in Brazil. The Dutch West India Company, founded in 1621, captured Bahia in 1624, giving them access to sugar, salt, and tobacco exports. Although the Dutch only occupied coastal Brazil until 1654, they established a lasting system of plantation-based sugar production that relied on the importation of slaves.
[378] Paine, *The Sea and Civilization*, 450.

established in Batavia sometime during the 17th century, in order to compile, control, and disseminate local navigational information.[379]

English

In the early 1500s, England "consciously chose to become a sea power."[380] Although its navy during this period "was not yet an effective instrument of state power," Queen Elizabeth I (reigned 1558-1603) regularly lent English ships to private commercial ventures.[381] Most notably, Queen Elizabeth sent Francis Drake on a covert mission to circumnavigate the globe, which he completed in 1580. The charts and maps Drake compiled on the journey were made state secrets immediately after.[382] News of Drake's route, which passed through the Straits of Magellan and up the coast of South America, caused Spain to protest the unauthorized trespass of its claimed sea territory (discussed below). Soon thereafter, other issues caused simmering tensions between Spain and England to boil over into maritime conflict. Although the English victory over the Spanish Armada in 1588 was largely the result of poor planning and administration on the part of the Spanish, the victory gave the English newfound confidence in their expansion into Spanish spheres of influence.[383]

England quickly became a typical mercantilist maritime power, and began expanding trade networks and projecting power across the global ocean. English merchants had established the joint stock Muscovy Company (1555) and Levant

[379] Schilder, "Organization and Evolution of the Dutch East India Company's Hydrographic Office in the Seventeenth Century."
[380] Andrew Lambert, "The Pax Britannica and the Advent of Globalization," in *Maritime Strategy and Global Order: Markets, Resources, Security*, ed. Daniel Moran and James Avery Russell (Washington, DC: Georgetown University Press, 2016), 6.
[381] Paine, *The Sea and Civilization*, 436.
[382] Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," 61.
[383] Paine, *The Sea and Civilization*, 438.

Company (1581) to exploit trading opportunities with Russia and the eastern Mediterranean, and this same model was used to create the East India Company in 1600. The English East India Company had fewer resources and less sophistication than the Dutch East India Company, but it profited from a high volume of trade in low value goods.[384] In 1612, the East India Company won a naval battle with the Portuguese outside Surat, Gujarat, which became the company's first headquarters of trade in India. The English eventually achieved dominance in Asian markets, establishing a colony in India, starting several wars with China, and generally using coercion to ensure preferential trade relationships.

The English state was actively involved in supporting and protecting English trade. A series of Navigation Acts in the mid-17th century declared that English trade must be in English vessels, with crews that were at least three-quarters English. All goods from English colonies had to be shipped to England, and all goods going to the colonies had to be shipped through England. The English perceived the Dutch to be their main trade competitor, and the Navigation Acts were essentially designed to exclude all trade with the Dutch. Overall, the Navigation Acts were followed and obeyed, although the English could not prevent some smuggling, especially to and from its colonies in North America. By the 19th century, the scope of the British Empire and hegemony of the Royal Navy were unrivaled among European maritime powers.

Mapping the World Ocean

Voyages of exploration in the 15th and 16th centuries "necessitated a radically new vision of the world and its oceanic reaches."[385] The task of collecting and systematizing

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[384] Ibid., 451.

[385] Martin W. Lewis, "Dividing the Ocean Sea," *The Geographical Review* 89, no. 2 (April 1999): 196.

geographic information initially fell to cosmography, a broad field concerned with the nature of the physical universe.[386] But because maps were so economically and politically valuable, the production of cartographic knowledge became "controlled, selected, organized, and redistributed according to definite procedures"[387] The creation, use, and dissemination of maps made exploration an iterative process: a voyage would bring back new charts, which the next voyage would use to navigate to the edge of the unknown. That voyage would then bring back new data for the next voyage. Much of the knowledge acquired was drawn from indigenes and settler communities, in addition to direct observation and, eventually, systematic surveying.[388] Maps and charts encoded the most important information acquired on these early voyages. They facilitated the expansion of trade networks and colonies and increased the safety and efficiency of navigation. Because geographic and cartographic information was so valuable, its collection, synthesis, and distribution was controlled by mercantilist states in the early modern period.

This section describes how and why the model of centralized and controlled geographic knowledge broke down. Although there were multiple motivations for collecting geographical data at any given time, in general the incentives shifted from strategic and economic advantage, to practical utility, to scientific knowledge production. Regardless of motivation, the resolution and precision of maps progressively improved throughout this period.

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[386] Denis E Cosgrove, *Apollo's Eye a Cartographic Genealogy of the Earth in the Western Imagination* (Baltimore: Johns Hopkins University Press, 2001), 95.
[387] Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," 59.
[388] Delbourgo et al., *Science and Empire in the Atlantic World*, 5.

Secret Cartography

During the 16th century, the European maritime powers exerted substantial effort to restrict access to the growing body of knowledge concerning geography, cartography, and navigation.[389] Because mercantilist states were jockeying for trade advantage, "a nation's knowledge of safe and efficient routes comprised a jealously guarded body of trade secrets."[390] Even states without centralized repositories of cartographic information, like England, controlled the dissemination of charts in an ad hoc way. Maps were concealed and censored, and sometimes falsified.[391]

The model of state secrecy over maps began to break down in the 17th and 18th centuries. Multi-national crews made it difficult to hide navigational information, and the dissemination of the printing press made it easier to circulate geographic information.[392] State and private actors invested in their own information-gathering expeditions, but also resorted to espionage and theft.[393] Pirates gained geographic information by capturing ships, stealing their documents, and interrogating their pilots. As time passed and more ships ventured to more places, secrecy became difficult or impossible to maintain.

But there were also economic and political reasons to make maps available. The growing number of users meant that to achieve the full benefit of maritime trade, maps needed to be available to merchants. Navigational charts not only revealed the location of routes, but were also an important means of reducing the vulnerability and fragility of ships in the sometimes-harsh maritime environment, by encoding information about shoals and other hazards. Maps and charts, when made public, could help legitimize

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389 Ibid., 33.
390 Paine, *The Sea and Civilization*, 518.
391 Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," 59.
392 Henry J. Perkinson, *How Things Got Better: Speech, Writing, Printing, and Cultural Change* (Westport, CT: Bergin & Garvey, 1995), 122.; Paine, *The Sea and Civilization*, 379, 441.; Delbourgo et al., *Science and Empire in the Atlantic World*, 37.
393 Harley, "Silences and Secrecy: The Hidden Agenda of Cartography in Early Modern Europe," 64.

territorial claims. Maps were a "visual language communicating proprietorial or territorial rights in both practical and symbolic senses."[394] State actors were therefore attentive to whether new maps represented demarcation lines in ways that might disadvantage them.[395] An "unstated compromise" emerged where maps that contained useful diplomatic information, such as latitude, longitude, and boundary lines, could be publicized while more detailed navigational charts maintained the status of trade secrets.[396]

To these two reasons for the decline of secrecy – loss of control and practical benefit – can be added a third: the emergence of scientific incentives, practices, and norms for data collection. Although 'oceanography' (not yet a distinct science) barely existed during this period, the exploration and cartography described above can be understood as the first phase of scientific investigation: observation and documentation. By the 18th century, cartography "was transformed from a description of the world into a scientific discipline expressed in mathematical terms."[397] The "gradual growth of the practice of making oceanographical observations at sea" must be understood in the larger context of the emergence of modern science.[398]

Filling in the World Map

Because it was Europeans who "filled in the map of the world," the maps they produced tended to be Eurocentric.[399] Many features of contemporary world maps, including the hierarchy of ocean divisions, the major constituent parts of the ocean, and

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[394] Ibid., 59.
[395] Delbourgo et al., *Science and Empire in the Atlantic World*, 30.
[396] Ibid., 40.
[397] Headrick, *Power over Peoples*, 44.
[398] Margaret Deacon, *Scientists and the Sea, 1650-1900: A Study of Marine Science* (Aldershot, Hampshire, Great Britain; Brookfield, Vt.: Ashgate, 1997), 194.
[399] Headrick, *Power over Peoples*, 51.

specific names, are all “rooted in a specifically European worldview.”[400] The British played a particularly central role in naming and describing new places, parts, and features of the world ocean. Three examples of British map-making over the 18th to 19th century demonstrate this shift from state-centric secrecy for economic and political advantage to scientific investigation for the sake of understanding the ocean.

The effort to understand ocean processes extended to the American colonies, where Benjamin Franklin published a series of charts in 1768, 1782, and 1786 that literally put the Gulf Stream on the map. This “landmark contribution to maritime cartography” served practical needs and satisfied scientific curiosity.[401] Franklin was interested in why the westward trip across the Atlantic took an average of 83 days, whereas the eastward trip only took 49 days (in the 1720s). He collected information from mariners, and especially whalers, who had better knowledge of the Gulf Stream because their occupation led them to explore its edges.[402] Until this time, seafarers' knowledge was poorly circulated on land, either because of lack of interest, or because of the “corporate ethic” of secrecy.[403] With the rise of the British Navy, the state declared “new authority over…maritime knowledge,” including the publication of maps, to assist with the expansion of the British Empire.[404] While Franklin's charts of the Gulf Stream were initially published in the service of this empire, his later releases expressed a pro-independence political orientation. Indeed, during the Revolutionary War Franklin “intended for copies to be given to all French ships supplying arms to the Americans.”[405]

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[400] Lewis, “Dividing the Ocean Sea,” 189.
[401] Delbourgo et al., *Science and Empire in the Atlantic World*, 89.
[402] Ibid., 87.
[403] Ibid., 75.
[404] Ibid.
[405] Paine, *The Sea and Civilization*, 519.

While maps of the Gulf Stream were initially intended to assist the British Empire, they ended up making secret mariners' knowledge visible and accessible for anti-imperial purposes.

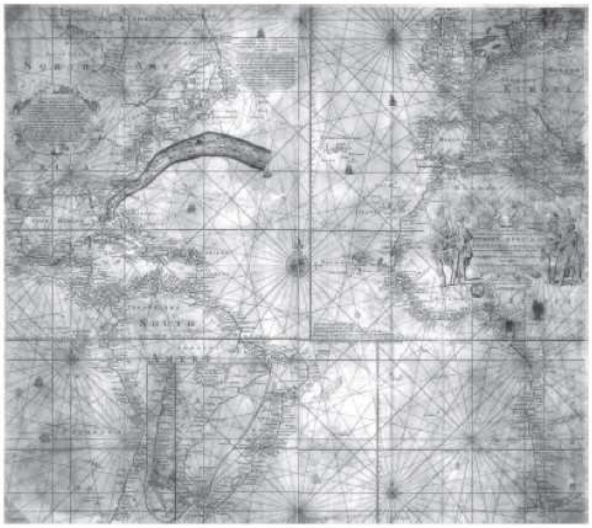

Figure 3.3 Benjamin Franklin and Timothy Folger, chart of the Gulf Stream ([London, 1768]). This is the first known chart of the Gulf Stream. Reproduction courtesy of the Library of Congress.

Figure 3.4 Benjamin Franklin "A Chart of the Gulf Stream," from "Maritime Observations," *American Philosophical Society Transactions* 2 (1786). This is Franklin's third and final Gulf Stream chart. He is at bottom right, conversing with Neptune. Reproduction courtesy of a private collector.

Figure 8 - Benjamin Franklin's second (left) and final (right) maps of the Gulf Stream, from Delbourgo, James, Nicholas Dew. Science and Empire in the Atlantic World. New York: Routledge, 2008. pgs. 89, 91

The three voyages of Captain James Cook (1768-79) represented a shift in the grand project of exploration. For the first time, "scientific work in general became an important feature of voyages of discovery from Britain."[406] The objective of Cook's first voyage was to observe the transit of Venus from Tahiti, an idea introduced by Edmond Halley several decades before. The primary purpose was therefore to contribute to the science of astronomy, which was an important aid to navigation. A secondary purpose was "the search for Terra Australis," a hypothetical southern continent that was believed to exist as a balance to the northern hemisphere.[407] This search motivated Cook's second voyage, which reached both the icy edges of Antarctica and Easter Island in the remote

[406] Deacon, *Scientists and the Sea, 1650-1900*, 185.
[407] Paine, *The Sea and Civilization*, 500.

southern Pacific. Cook's third expedition set out to find a Northwest Passage, for which Parliament had offered a substantial prize. He did not find a Passage, but his ships reached both the Bering Strait and the Hawaiian islands (where he was killed in a skirmish with locals). The voyages of Captain Cook were extremely successful, in part because his "strict regimen for cleaning and airing the ship" improved the health and resilience of his crews.[408] Cook charted numerous oceanic islands, "laying the groundwork for the first accurate map of the Pacific."[409] Many of the places Cook discovered are named after him, including the Cook Strait (between the big islands of New Zealand), the Cook Inlet (in Alaska), and the Cook Islands (in the south Pacific). After his three expeditions, only a small number of Polynesian islands remained unmapped.[410]

In the 1800s the British Navy increased its investment in the collection of scientific data, most notably in the voyage of the H.M.S. *Challenger* (1872-6). This large-scale expedition was proposed by the British Royal Society, which hoped to "combine the various lines of inquiry that were coming to define the discipline of oceanography."[411] In a trip of over 1000 days and 68,000 miles, six civilian scientists recorded depth and temperature data, measured currents and took water samples, and dredged the seabed. In addition to discovering over 4000 new species, the *Challenger* expedition made a substantial contribution to the development of marine geology. Its scientists discovered the existence of manganese nodules strewn across the seafloor, and located the deepest point in the ocean, named 'Challenger Deep.' The expedition's *Challenger Reports* were

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[408] Ibid.
[409] Finney, "The Other One-Third of the Globe," 287.
[410] John Noble Wilford, *The Mapmakers*, 2. Vintage Books ed., ed (New York: Vintage Books, 2001).
[411] Paine, *The Sea and Civilization*, 540.

published between 1880 and 1895, and included 50 volumes with 29,000 pages. Among other things, they contained data that "established the existence of density circulation beyond all reasonable doubt."[412] One lasting legacy of the *Challenger* expedition was its creation of a network of researchers with a common focus: understanding the ocean.

What the Maps Missed

The maps created during the early Age of Expansion can be described as 'distorted portraits' for many reasons, but in particular, the diversity of maritime fauna "remained virtually unknown."[413] The process of discovery and documentation included no real investigation of ecology, because seafarers were more concerned with trade routes, wind patterns, and coastal geography. When early mapmakers depicted unexplored regions, they often populated them with sea monsters as a warning to seafarers. These creatures were actually based on a small number of unscientific observations, including the accounts of sailors and decaying carcasses washed up on beaches.[414] Ecosystems were known only through folk knowledge from fishers, sealers, and whalers for many centuries. Targeted scientific inquiry into fisheries only arose when academic zoologists began to specialize in marine life in the late 1800s, and some western governments sponsored coastal research sites. While over-exploitation occurred in some coastal fisheries, the problem was not significant, recognized, or acted upon until the modern era.

Limitations in data collection – because of imposing marine geography, rudimentary technology, and lack of scientific professionalization – inhibited the

[412] Deacon, *Scientists and the Sea, 1650-1900*, 348.
[413] Grace Costantino, "Five 'Real' Sea Monsters Brought to Life by Early Naturalists," *Smithsonian*, October 27, 2014.
[414] Ibid.

formulation of detailed, durable, and useful scientific theories during this period. This relatively limited scientific understanding meant ignorance of the full suite of ocean resources, and also made the concept of human damage to the ocean environment virtually unthinkable. Although geographic knowledge expanded rapidly during this period, maps of islands and coastlines in the Indian, Atlantic, and Pacific Oceans still lacked detail and precision. Limitations on geographic knowledge, the near total absence of ecological knowledge, and the growing technological capabilities of European ships, created a specific context for the formation of international law of the sea.

Regime Formation

The concept of an 'ocean governance regime' is anachronistic for the early part of this period. Before the 19th century, rules of ocean use were rarely developed explicitly and collectively, or codified in documents understood as international law. But social and political institutions did form from repeated practices and juristic theorizing, described as 'customary international law.'[415] Particular actors – European maritime entrepreneurs and sea powers – exercised a 'practical authority' in the creation of normative maritime practices.[416] This section considers two historical trends in the development of the modern ocean governance regime: the extension and retraction of territorial claims, and the shift from support to prohibition of piracy and privateering. Although conflict over fisheries did play a role in shaping maritime political geography in the early modern period, conflict over trade routes and security from predation loomed larger.

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415 Michael Byers, *Custom, Power, and the Power of Rules: International Relations and Customary International Law* (Cambridge [England] ; New York: Cambridge University Press, 1999); Rothwell R. Donald, *The Oxford Handbook of the Law of the Sea* (New York, NY: Oxford University Press, 2015).
416 'Practical authority' is "the problem-solving capabilities and recognition from key decision makers that allow [organizations] to influence public or private behaviors." This definition is taken from Rebecca Abers and Margaret E. Keck, *Practical Authority: Agency and Institutional Change in Brazilian Water Politics* (Oxford: Oxford University Press, 2013).

A common theme during the Age of Expansion was close commercial and state partnerships in the effort to monopolize lucrative routes to the Indian Ocean and the Americas. In terms of the exercise of power, these relationships make it difficult to distinguish the actions and intentions of private and public actors. States often authorized private actors to use violence against non-nationals, as in the letters of marque system that legitimized privateering. At other times, especially in the 18th and 19th centuries, the application of naval power would serve the economic interests of co-national merchants and traders. European mercantilist states – especially the Portuguese, Spanish, Dutch, and English – all had the individual goal of controlling trade routes, and therefore "put a high premium on exercising social power at sea."[417] Maritime states desired the protection of their own ships, and the predation of others (although the shared benefit of anti-piracy protection was a common justification for claims). The earliest contributions to the modern ocean governance regime were forged in this crucible of competing European interests.

The Europeans introduced the idea of dividing the ocean into parts, for the exercise of national political control over a space analogous to territory on land.[418] The early modern period includes two notable attempts to territorialize broad swaths of the global ocean. In the early Age of Expansion, the Portuguese and Spanish made vast territorial claims in the ocean. The Treaty of Tordesillas, discussed below, divided the world ocean in half before Vasco da Gama had rounded the tip of Africa (1498) and Ferdinand Magellan's expedition had circumnavigated the globe (1520). As Iberian maritime power waned, emerging competition between the English and Dutch sparked an

[417] Steinberg, *The Social Construction of the Ocean*, 71.
[418] Paine, *The Sea and Civilization*, 338.

international legal debate about the status of the oceans, and in particular whether or not they could be territorialized. This debate, which pitted English and Iberian territorial claims against a Dutch concept of free seas, took place before the Pacific was mapped and longitude could reliably be determined. This section surveys the relevant history, with special attention to the relationship between cartography, geography, and international law of the sea.

Territorialization

After the "shared experience in the discovery and exploitation of the Atlantic archipelagos," Spain and Portugal embarked on separate imperial projects.[419] The 1479 Treaty of Alcáçovas divided the Atlantic archipelagos between the two Iberian powers, giving the Canary Islands to Spanish Castile, and allowing Portugal to retain ownership over Madeira, the Azores, and the Cape Verde Islands. The Treaty also gave the Portuguese "free rein in the exploration of the Atlantic."[420] The Portuguese continued the work of Henrique the Navigator, exploring the Gulf of Guinea, which a Papal Bull of 1455 had declared their legitimate possession. In contrast, the Spanish sponsored voyages to the north and west in the Atlantic, from the launching point of the Canary Islands. After the successful voyage of Columbus to a landmass he thought was Asia, the Portuguese King João claimed that the Spanish had violated the terms of the Treaty of Alcáçovas.[421] Columbus argued that the islands he had discovered were actually an extension of the Canary Islands archipelago, "when patently they were not."[422] Both Spain and Portugal wanted clarification, so the Spanish lobbied the Pope to recognize

[419] Ibid., 407.
[420] Ibid., 388.
[421] Ibid., 396.
[422] Ibid., 397.

their claim. A series of four Papal Bulls caused more confusion about the division of claims, so the Iberian powers negotiated the 1494 Treaty of Tordesillas, which clarified the demarcation line with reference to the Canary Islands.

The Treaty of Tordesillas assigned the southern Atlantic and Indian Oceans to Portugal, and the northern Atlantic to Spain. But it was quickly discovered that the line created by Tordesillas transects the easternmost tip of South America, thereby legitimating Portuguese colonization of Brazil. This unintended result occurred because of incomplete and imprecise maps at the time the Treaty was negotiated. In the 1520s, Magellan and de Elcano's successful circumnavigation of the Earth (sponsored by the Spanish) created another issue for the Treaty of Tordesillas. Because the Earth is spherical, figuring out where one Iberian state's domain ended and the other's began required drawing another line. The specific location of the dispute was the Spice Islands (Maluku Islands), which Portugal had reached in 1511, and from which could be procured valuable spices such as nutmeg, cloves, and mace. The 1529 Treaty of Saragossa merely drew another longitudinal line in the Pacific, such that the whole world was divided into unequal halves, with all ocean space claimed by one or the other Iberian power.

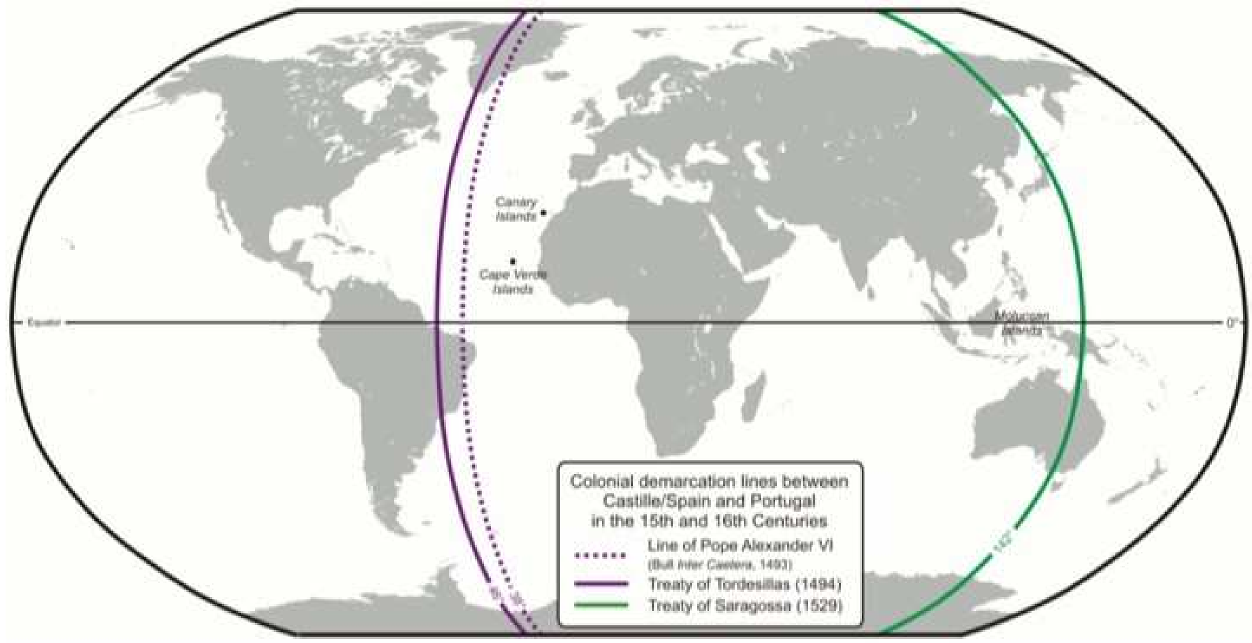

Figure 9 - Treaties of Tordesillas and Saragossa, From Wikipedia, licensed under Creative Commons

Many scholars argue that the Treaties of Tordesillas and Saragossa were straightforward territorialization; "the historical moment in which the appropriation of land was no longer something distinct from the appropriation of the sea."[423] But Philip Steinberg rejects this comparison in *The Social Construction of the Ocean*, suggesting instead that the treaties are better understood as "an allocation of routes for movement and spheres for exploration rather than an allocation of boundable, claimable territory."[424] Steinberg is interested in how the Papal Bulls and Treaties reflect and reinforce the "logic of mercantilism."[425] But his detailed investigation of primary and secondary texts actually reveals centuries of heated disagreement about what the Treaties exactly meant, and how actors at the time understood and interpreted them.

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[423] Aleksandra Elizabeth Thurman, "The Justification of the Law of the Sea in Early Modern Europe" (Dissertation, University of Michigan, 2010), 73, Dissertation Abstracts International (3441626).
[424] Steinberg, *The Social Construction of the Ocean*, 86.
[425] Ibid.

There is a more fundamental reason why Tordesillas did not create ocean territory that is equivalent to land territory: the ocean is fluid, and therefore cannot be easily partitioned. If the Papal Bulls and Iberian treaties did intend to create traditional territorial borders, this would be a "the imposition of legal fiction onto geographical fact."[426] Unlike land territory, ocean territory could not be permanently marked or defended by the construction of walls and other border infrastructure. But Steinberg's suggestion that this difference means the Treaties could not be an act of territorialization implies that Europeans had a pre-formed cognitive and political model of 'territory' that they could draw upon, but chose not to. In fact, international politics during the Age of Expansion actively shaped an inchoate and malleable concept of territory: "the New World proved to be a laboratory where ideas were tried out, concepts forged, and techniques tested and perfected."[427] In other words, the Treaty of Tordesillas can be understood as an act of territorialization, even if it did not create the equivalent of modern land territory.

Stuart Elden argues in *The Birth of Territory* that Tordesillas represents a model of territoriality "that the actual techniques only later caught up with."[428] Because longitude could not be reliably determined at this time, cartographers found it challenging plot the demarcation line relative to known coastlines. The way the Treaties of Tordesillas and Saragossa divided territory between Portugal and Spain was fundamentally new, because it used a calculative and deductive measure to divide land and ocean space that had yet to be discovered, documented, or occupied. As opposed to

[426] Henry Jones, "Lines in the Ocean: Thinking with the Sea about Territory and International Law," *London Review of International Law*, June 17, 2016, 20.
[427] Stuart Elden, *The Birth of Territory* (Chicago ; London: The University of Chicago Press, 2013), 245.
[428] Ibid., 242.

being different than territorialization, this act can be understood as an innovation on territorialization. In embracing an abstract and calculated border, the Iberian powers were rejecting the idea that "simple occupation led to possession."[429]

A little over a century after the Treaty of Tordesillas, England's naval capacities had advanced considerably, and the English crown resurrected territorial claims over the British Seas made in prior centuries. These claims had a starting point – the English coastline – but no clear boundary marking their extent. In 1609, King James I asserted exclusive rights to coastal fisheries in an attempt to obstruct Dutch fishing. King Charles I (reigned 1625-49) expanded the claim of absolute sovereignty to exclude all foreign military vessels, and to require foreign commercial ships to 'strike the flag' in a sign of deference upon meeting the English fleet. These claims were clarified and defended by John Selden's *Of the Dominion, or, Ownership of the Sea* (also known as *Mare Clausum*), published in 1635. Selden's description of the extent of British seas, despite being "absurdly expansive" and including all of the North Atlantic, was generally adopted in the following decades.[430]

These two territorialization projects were driven by the hegemonic desire for a monopoly over trade and commerce, and were part of a larger process of early modern European state building. Territorialization was, however, very ineffective at shaping patterns of practice. Borders could be neither precisely defined nor effectively defended, because of limitations in geographical knowledge and technological capabilities. Earlier claims to dominion or possession, such as by Venice in the Adriatic Sea or Scandinavian states in the Baltic Sea, utilized obvious and well-known natural boundaries (primarily

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[429] Ibid., 242–43.
[430] Fulton, *The Sovereignty of the Sea*, 20; Paine, *The Sea and Civilization*, 447.

coastlines). In contrast, the declarations made by Portugal, Spain, and England claimed vast areas in the open ocean. The inability to ascertain longitude (until the invention of the marine chronometer in 1761) meant that the precise location of islands and distant coastlines could not be determined with much accuracy, and cartographic representations of space were particularly malleable.[431] In other words, these official borders meant practically nothing to users of the global ocean. Its vastness made consistent surveillance and interdiction of violators impossible, so the territorial claims had little deterrent effect on foreign merchants, navies, and pirates.

Like the Iberian claims, the broad declaration of 'British Seas' also had major issues with delimitation and enforcement. But in this case, the malleability of the British territorial claim actually allowed the political borders to sync up with geographical and technological realities. Until the 17th century, the "Sea of England" was merely a "political expression" with no formal demarcation.[432] In 1610, one year after King James' declaration of exclusive fishing rights, a Dutch delegation to England broached the idea that "the maritime dominion of a state ended where its power of asserting continuous possession ended."[433] This "principle of compulsion" appears in Hugo Grotius's 1625 *Law of War and Peace*, but was generally ignored as a principle of international law until 1702 when another Dutchman, Cornelius van Bijnkershoek, proposed that the distance of a cannon shot from shore define the territorial sea.[434] This proposal to use functional control from the shore as a delimitation principle resonated with a strong early incentive for ocean governance: the maintenance of order and suppression of piracy. This "decisive

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431 Cosgrove, *Apollo's Eye a Cartographic Genealogy of the Earth in the Western Imagination*, 94.
432 Fulton, *The Sovereignty of the Sea*, 16.
433 Ibid., 549.
434 Thurman, "The Justification of the Law of the Sea in Early Modern Europe," 136.

property of compulsion and dominion" would be "transferred in theory to all parts of a coast."[435] The principle of compulsion, and more specifically the 3-mile 'cannon shot' norm, did not command immediate assent, but by the end of the 18th century the 3-mile territorial sea was widely accepted. The United States was the first to officially declare a 3-mile territorial sea in 1793, when it needed to define a neutral zone in the recently sparked war between France and Great Britain.[436]

Freedom of the Seas

This narrowing from territorialization of huge swaths of ocean to a 3-mile territorial sea is part of a more general takeover of customary international law by the 'freedom of the seas' doctrine. Classical Roman jurisprudence regarded the ocean as "property of all people," common and freely accessed, not subject to appropriation.[437] But in the medieval period, European maritime powers had begun claiming dominion over regional seas, and in the 15th century the Iberian powers made expansive territorial claims. The increasing density of maritime trade, improvements in cartographic representation, and conflicts over routes and entrepôts set the stage for the formation of new international law – customary or formal – for managing global ocean space. In the early 17th century, jurists from the Dutch Republic, England, and Portugal had an extended debate about the legal and political status of the Earth's ocean.

The proximate cause for the so-called 'Battle of the Books' was a multi-year conflict between Dutch and Portuguese ships in Southeast Asia. In 1600, two Dutch ships sailed to "investigate the possibility of establishing a Dutch presence in China."[438] The

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[435] Fulton, *The Sovereignty of the Sea*, 558.
[436] Ibid., 573.
[437] Paine, *The Sea and Civilization*, 388.
[438] Ibid., 443.

first ship landed at Macau in 1601, and sent a delegation to the Portuguese, who had been effectively renting Macau from the Ming Dynasty since 1557.[439] The Portuguese, fearing encroachment on their lucrative China trade, slaughtered most of the delegation. The other Dutch ship, which had been investigating trading opportunities elsewhere, found out after it seized a Portuguese ship and discovered letters detailing what had happened at Macau. Encouraged by a local ruler, the captain of the second Dutch ship decided to wait in the Singapore Strait to ambush a Portuguese ship traveling from Macau to Melaka. In 1603, the Dutch bombarded and captured the *Santa Catarina*. The booty from this prize was auctioned in Amsterdam, where it earned "enough to build fifty or sixty merchants' houses."[440]

Portugal challenged the legality of the capture, and Dutch East India Company shareholders questioned its wisdom and morality.[441] The Dutch captain van Heemskerck had no official letter of marque, but before the ambush he drafted a document of legal justifications, which he had his officers sign. A Dutch court declared the prize valid, but the Dutch East India Company asked Hugo Grotius to draft a justification of the ruling. The Dutch East India Company was "both a trading entity and an instrument of the state…invested with powers to wage war, contract treaties, establish forts, administer the law, and in most respects act as an arm of the Dutch government."[442] Grotius was therefore defending the Dutch interpretation of customary international law of the sea. Although the proximate conflict was between the Dutch and Portuguese, Grotius

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[439] Macau was administered by Portugal under the authority of the Chinese. The Portuguese established a permanent settlement and paid an annual tribute.
[440] Paine, *The Sea and Civilization*, 444.
[441] R. P. Anand, *Origin and Development of the Law of the Sea: History of International Law Revisited*, Publications on Ocean Development, v. 7 (The Hague ; Boston : Hingham, MA: Martinus Nijhoff ; [distributed in the U.S. by] Kluwer Boston, 1983), 78.
[442] Ibid., 442.

formulated general arguments designed to rebuff Iberian and English sovereignty claims. His arguments relied heavily on "classical antecedents," but their re-articulation was necessary in light of growing imperial competition and broad territorial claims.[443]

Out of Grotius's larger work *The Law of Prize and Booty*, one chapter was published anonymously in 1609. In *Mare Liberum* (The Free Sea), Grotius marshaled a diversity of arguments against the Portuguese claim to sovereignty in the Indian Ocean. He argued that Portugal had no right to sovereignty or exclusive possession, whether based on discovery, papal donation, war, occupation, prescription, or custom. More generally, Grotius argued that the ocean was fundamentally unlike the land: it was bigger, you could not occupy it, and its primary resources (navigation and fishing) were inexhaustible.[444] For these reasons, the arguments used to justify sovereignty and property over land did not easily apply to the ocean.[445] Grotius declared that these fundamental differences with land-space meant that the ocean was part of the realm of natural law, and no part of it could be claimed as the exclusive domain of a state. In other words, the concept of territorial sovereignty did not extend into ocean-space. This exclusion of the sea reversed the implicit assertion of Tordesillas that territorialization could be applied to ocean space, and reaffirmed the connection between territory and terrestrial space, which could be "bounded and organized into discrete spaces."[446]

Ocean-space was "expressly defined as outside of state territory," but for Grotius this did not make the sea *res nullius*.[447] Far from waiting to be discovered, the ocean had

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[443] Ibid., 440, 445.
[444] Steinberg, *The Social Construction of the Ocean*, 91.
[445] David Armitage, *Foundations of Modern International Thought* (Cambridge ; New York: Cambridge University Press, 2013), 52.
[446] Steinberg, *The Social Construction of the Ocean*, 92.
[447] Ibid., 11, 93.

been used to human advantage for all of human history. Grotius saw the ocean as a space where the international community exists and international interactions take place. This conception of an abstract arena reflected the primary use of the ocean during the early modern and modern period: as a transportation surface, a plane of circulation. At this time, renewable resources like fish seemed inexhaustible, and non-renewable and stationary resources like oil and minerals were unknown. The focus on trade routes and power projection on the surface constructed ocean-space as an abstract zone of channeled circulation to be managed, as opposed to a set of variegated places to be claimed. Grotius proposed a principle of *res extra commercium*, in which the ocean was understood as a communal zone of free exploitation.[448] This open arena created an international community of users, but Grotius rejected the notion of communal ownership. Users were required to conserve ocean resources, but had no obligation to share their maritime profits.[449] In other words, Grotius rejected the principle of *res nullius* in favor of a form of *res communis*, but did not go as far as to establish or imply a *res publica* regime.

Two responses to *Mare Liberium* represented the views of competing maritime powers.[450] The English response – John Selden's *Mare Clausum* – was written at the request of the English crown in 1618, but not published until 1635. Selden made no arguments about the open ocean, but forcefully asserted that possession was possible where the sea could be controlled. Seraphim de Freitas wrote the semi-official Portuguese response, and argued that sovereigns could legitimately claim authority over navigation and trade routes. But instead of proposing possession of ocean space, Freitas favored

[448] Ibid., 89.
[449] Ibid., 93.
[450] Ibid., 90.

"exclusive usufruct rights" over specific long-distance routes.[451] Despite these counter-arguments against the strong 'freedom of the seas' doctrine, the principle espoused by Grotius and the Dutch eventually became the foundation of modern customary international law. The English came to support the free seas doctrine relatively quickly, as their merchant marine and naval forces grew in numbers and strength. Rather than acquiescence to the Dutch proposal, the English embrace of 'freedom of the seas' could be understood as a return to the original doctrine of Queen Elizabeth I (reigned 1558-1603), the predecessor of James I.

The 'freedom of the seas' doctrine became customary international law instead of territorialization and sovereign possession, for two basic reasons. First – territorial borders in the ocean were impractical in implementation. The difficulty of locating exact borders on imprecise maps was compounded by the inability to surveil and enforce exclusion across broad swaths of the ocean. Indeed, the much-reduced 3-mile territorial sea was proposed and adopted precisely because the border could be easily apprehended and enforced. In short, broad territorialization was not feasible because of the geophysics of the ocean and the technology of early modern maritime states. If territorialization had proven feasible, an alternative European tradition – of dominion in the Baltic, Adriatic, and Ligurian Seas – may have been globalized. Second – increasingly powerful actors had an interest in free navigation. The English and Dutch would not have been able to establish global trading networks if ocean space was partitioned. During this period, European maritime states were more focused on imperial expansion than fighting on European shorelines. The freedom of the seas doctrine "encouraged broader participation

[451] Ibid., 96.

in intercontinental trade."[452] These two reasons – the inability to partition and the preference for free commerce – demonstrate that the *res communis* regime established by Grotius came about by both default and design.

Piracy and Privateering

Predation by pirates has existed as long as maritime commerce, and during the medieval period piracy plagued both the northern and southern European maritime communities. Early territorial claims in the Mediterranean and North Sea were often justified by the need to provide safety for maritime commerce.[453] Indeed, a state's responsibility for redressing piracy along its coastline was the first "practically derived norm" in anti-piracy customary international law.[454] As European maritime communities began to merge and interconnect in the early modern period, piracy remained a major problem. Merchants' associations, and later sovereign authorities, organized to "maintain by force the security of navigation in the common interest."[455] But the problem got more difficult to solve as trading networks ventured farther from home territories, into the Atlantic, Indian, and Pacific Oceans. European merchants encountered new sources of piracy, such as the "active antagonism" from Oman, but also brought European piracy to new places.[456] And eventually, pirate enclaves emerged in locations like Madagascar and the Caribbean, either in quasi-states or with the blessing of local rulers. In the 17th

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[452] Paine, *The Sea and Civilization*, 440.
[453] Fulton, *The Sovereignty of the Sea*, 30; Steinberg, *The Social Construction of the Ocean*, 62.
[454] Janice E. Thomson, *Mercenaries, Pirates, and Sovereigns: State-Building and Extraterritorial Violence in Early Modern Europe*, Princeton Studies in International History and Politics (Princeton, N.J: Princeton University Press, 1994), 116.
[455] Fulton, *The Sovereignty of the Sea*, 6.
[456] Paine, *The Sea and Civilization*, 454.

century, a new scale and scope of organized piracy, in addition to privateering sanctioned by rivalrous states, threatened the safety of long-distance trading ships.[457]

Although the European maritime states were the primary victims of predation during this period, their own actions amplified the problem of non-state violence at sea. Counter-intuitively, predation got worse as a result of European efforts to solve the problem of security at sea in the absence of powerful navies. Two separate practices developed. First, states issued 'letters of marque' in peacetime, which "allowed individuals to seek redress for depredations they suffered at the hands of foreigners on the high seas."[458] Commonly used since the 14th century, letters of marque were a practical way for governments to resolve private international disputes without having to mobilize military resources. The second practice, privateering, was used by states in wartime to supplement their naval capacity. Privateers were officially authorized to attack enemy commerce, and allowed to keep a portion of their spoils. Many states initially regulated the practice closely, requiring privateers to obtain prior consent for attacks, post bond to ensure compliance with instructions, and/or submit their spoils to inspection. Until the 19th century, privateering was used as "both a substitute and a foundation for state naval power."[459] These two systems – letters of marque and privateering – became confused and conflated, as states relied more and more on private ships to commit useful violence in the interests of the home country. When private ships were called in and out of the military service of the state, their crews developed the skills and the taste for maritime predation. When former privateers become pirates, European states would make a

[457] Thomson, *Mercenaries, Pirates, and Sovereigns*, 45–46.
[458] Ibid., 22.
[459] Ibid., 26.

nominal effort at suppression, until offering them pardons in exchange for privateering in the next war.[460] In short, "privateering generated organized piracy."[461]

European maritime states had many reasons to accept and even support piracy by co-nationals. Piracy weakened the competition and could break rival trade monopolies, bringing "scarce goods at affordable prices" to European markets.[462] The Portuguese engaged in piracy in the Indian Ocean, and English colonial governors endorsed English piracy in the Caribbean.[463] In the American colonies, piracy offered an investment opportunity for the wealthy and created a "thriving business" for provisioning ships.[464] England manipulated the legal status of piracy to serve its own interests; in the 15th century, Parliament passed strict anti-piracy laws but made no effort to suppress English piracy.[465] Indeed, England gained naval superiority over Spain in part through the actions of the 16th century Elizabethan 'Sea Dogs,' who "engaged in all kinds of violent activities against Spain in the New World."[466] Many of these English pirates were later rewarded with knighthood or a position in the Royal Navy.[467] Like the letters of marque system and privateering, piracy and privateering became difficult to distinguish, and in the 17th and 18th century the widespread presence of both started to be seen as a problem.

More specifically, piracy and privateering became less useful to the increasingly powerful England, which became Great Britain in 1707. In the 17th century, two forms of innovative financing laid the foundations of British naval hegemony: Charles I's writs for

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460 Ibid., 54.
461 Ibid., 43.
462 Ibid., 107–8.
463 Paine, *The Sea and Civilization*, 452, 456.
464 Thomson, *Mercenaries, Pirates, and Sovereigns*, 50.
465 Lucas Bento, "Toward an International Law of Piracy Sui Generis: How the Dual Nature of Maritime Piracy Law Enables Piracy to Flourish," *Berkeley Journal of International Law* 29, no. 2 (2011): 402.
466 Thomson, *Mercenaries, Pirates, and Sovereigns*, 23.
467 Ibid., 107–8.

'ship money,' a kind of taxation that went directly to the Navy, and the establishment of the Bank of England, which created new opportunities for financing.[468] By the early 18th century, Great Britain had the most powerful navy in the world, in large part because of its bureaucratic and systematic administration, and sophisticated convoy and blockade strategies.[469] In the 19th century, multiple technological innovations in shipbuilding, ship repair, and communications would work to Britain's advantage, solidifying and expanding its naval hegemony. The British built a "global network of naval bases and commercial harbors," outfitted with dry dock repair capability, and connected via submarine telegraph cable.[470]

The emergence of British naval hegemony provided both motive and means to end non-state violence at sea. As a result of its growing naval capacities, Britain no longer needed to rely on undisciplined privateers. Privateering became a weapon of weaker states; the Americans used it against Britain during the Revolutionary War and the War of 1812.[471] Great Britain regarded privateering as "the only real threat to its naval supremacy," and therefore defined it as a problem.[472] Piracy also plagued the emerging British Empire more generally. The British East India Company first pressured the British government to address the problem of piracy based in Madagascar. Because the pirates were English-speaking, rulers in India suspected the company of collusion and exacted retribution against English merchants for the actions of English pirates.[473] Although these specific events prompted British action against piracy, it was also

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[468] Paine, *The Sea and Civilization*, 483.
[469] Ibid., 470–71.
[470] Lambert, "The Pax Britannica and the Advent of Globalization," 11.
[471] Thomson, *Mercenaries, Pirates, and Sovereigns*, 26.
[472] Ibid., 144.
[473] Ibid., 48.

generally understood to hurt trade revenues, by reducing the number of ships that reached their destination, increasing insurance rates, and requiring outlays and cargo space for guns and men to shoot them. [474]

The British targeted piracy first, with some success. Even with organized and targeted effort, anti-piracy policing is very difficult, because the vast expanses of the ocean inhibit the easy identification and pursuit of pirates. The British strategy involved expanding the reach of both jurisdiction and enforcement. In 1699 Parliament established a system of vice-admiralty courts across the empire, to expedite the trial and punishment of captured pirates.[475] The Royal Navy destroyed pirate strongholds in the Caribbean, and patrolled Madagascar to deter the establishment of new ones. In 1721, Parliament passed a law that "made trafficking with pirates and furnishing them with supplies crimes of piracy."[476] By 1730 the British had succeeded in suppressing the 'Golden Age of Piracy,' due to these and other laws and activities.[477] The power concentration of British naval hegemony, and its dispersion across a globally interconnected network of bases, contributed greatly to the effectiveness of anti-piracy measures. British anti-piracy efforts demonstrate "how successful a singular, coextensive geographic and jurisdictional approach to piracy can be."[478] But British efforts were not entirely successful, in part because privateering continued; even British privateers were attacking British commerce.[479] Despite a century of anti-piracy efforts, the early 19th century was "the most violent and lawless period of maritime warfare in modern history" because of the

474 Lambert, "The Pax Britannica and the Advent of Globalization," 21.;Paine, *The Sea and Civilization*, 503.
475 Thomson, *Mercenaries, Pirates, and Sovereigns*, 50.
476 Ibid., 53.
477 Ibid., 54.
478 Bento, "Toward an International Law of Piracy Sui Generis: How the Dual Nature of Maritime Piracy Law Enables Piracy to Flourish," 401–2.
479 Thomson, *Mercenaries, Pirates, and Sovereigns*, 70.

predation of privateers and 'quasi-privateers.'[480] Because the line between piracy and privateering was so fuzzy, and because privateering had ceased to be closely regulated by governments, the same actions simply continued under a different guise; "Piracy could not be defined, much less suppressed, until privateering was abolished."[481]

States began placing restrictions on privateering in the late 18th century, but the practice was not abolished until the 1856 Treaty of Paris. The Treaty formally ended the Crimean War, and established new rules of wartime commerce. This formal international agreement, in which seven major powers simultaneously gave up the right to authorize privateering, was a reversal of centuries of customary international practice.[482] It was Great Britain that pushed for the prohibition of privateering, and the other powers agreed in exchange for ending "the British practice of interdicting neutral ships in search of contraband."[483] Although the Treaty of Paris was not complied with right away – the Confederacy commissioned privateers in the US Civil War – the practice had ended by the late 19th century, and no privateers were used during the 1898 Spanish-American war.[484] Outlawing privateering helped solve the problem of predation at sea more generally, because it facilitated the universalization of international norms against piracy.[485]

Although ending privateering was necessary to define and outlaw piracy, it also created a system that could not solve piracy in the long term. The prohibition on privateering ended the responsibility of the state over its violent nationals. Privateers had

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480 Ibid., 24.
481 Ibid., 144.
482 Ibid., 69, 75, 144.
483 Ibid., 72.
484 Ibid., 76.
485 Ibid., 117–18.

committed violence "under the authority of a state that accepts or is charged with responsibility for [their] acts."[486] In the 1856 Treaty of Paris, states gave up their ability to authorize and take responsibility for the violent actions of private nationals. After the Treaty of Paris, only sovereign violence from national militaries was sanctioned on the ocean. This severed the connection between sovereign power and sovereign jurisdiction: national ships were floating pieces of territory under sovereign jurisdiction, but not themselves legitimate agents of the state. A three-tier system was created: state military ships that could commit sovereign violence, 'flagged' national ships that were under sovereign jurisdiction, and non-flagged, non-national ships. This severance of nationality and sovereignty meant that the prohibition on piracy had a problem: if a state was not responsible for the violence of its nationals, then who was responsible for stamping out piracy on the high seas?[487]

The territorialization strategy, whereby any ship without a foreign flag was considered a pirate, could have solved this problem by extending the norm about anti-piracy efforts in the territorial sea to broader swaths of the ocean. Under this strategy, Spain would be able to code any non-Spanish ships in the North Atlantic as pirates, and Spain would be responsible for quashing them. But, as we have seen, the territorialization strategy failed for a geographic and technological reason: such territories were very difficult to patrol and enforce.

Another possible approach was maintaining a stronger connection between nationality and sovereign jurisdiction, so that "the national origin of the pirate should determine

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[486] Ibid., 22.
[487] Ibid., 116.

which state was responsible for his acts."[488] One obstacle to this approach was that many pirates disavowed any nationality, or even claimed allegiance to a pirate commonwealth. But in cases where nationality could be at least ascribed to a pirate, because of language perhaps, states refused to accept responsibility. Janice Thomson suggests that the norm of state responsibility for nationals on the high seas did not catch on because "sovereignty and nationality could be entirely divorced."[489] Her argument for what caused the divorce was multi-national crews flying under a sovereign flag. To that I add another argument: when the ban on privateering disconnected nationality from the right to sovereign violence, it also disconnected nationality with sovereign jurisdiction on the high seas. What mattered for enforcement purposes was whether one's ship was a piece of floating territory, not whether its crew had national affiliation. Nationality was replaced with territory for the purpose of creating a community subject to state jurisdiction.

The anti-piracy norm that did become internationalized does not compel or encourage enforcement: "no state is responsible for the acts of pirates, and therefore no state can be held accountable for them."[490] Because piracy is outlawed across the ocean (eventually British laws became international law), states have the right to enforce anti-piracy law. But because the connection between nationality and sovereignty was severed, states do so with discretion, because they have no duty to capture and prosecute pirates.[491] Piracy was now easy to identify – any ship without a flag was a pirate – but without a flag, there was no 'flag state' specifically tasked with capture and prosecution. The anti-piracy regime solved the distinctiveness issue, whereby piracy and privateering

[488] Ibid., 117.
[489] Ibid.
[490] Ibid.
[491] Ibid., 108, 117.

could not be easily distinguished or differentiated, by making the flag the mark of sovereign jurisdiction.

This system was relatively effective during the *Pax Britannica*, the era of British naval supremacy, exactly because of that supremacy. But even when a maritime hegemon does have reason to act on the right to capture and prosecute pirates, the vast geography of the ocean makes this a very difficult task. Almost everywhere in the open ocean is a decent place to hide. Without a powerful and motivated enforcer, the anti-piracy regime is ineffective at solving the problem of piracy.

Conclusion

This chapter illustrates several geographic and technological influences on the formation of the early modern ocean governance regime. It was superior ship and navigation technology that propelled Europeans across the global ocean before other seafaring traditions. Geographic information had tremendous importance for actors seeking advantage through navigation across the ocean, so maps were carefully controlled. Secrecy eventually broke down, and maps became more accurate and available, in part because the ocean is accessible from all coastlines. And the vastness of the ocean made it difficult for any actor to control where ships could and could not go. Despite this size and fluidity, the Portuguese, Spanish, and English attempted territorial partition in the ocean. Territorialization in the open ocean failed, and the territorial sea was reduced to the 3 miles from the coastline that could be controlled with weapons. In the open ocean, territory was replaced with the ‘freedom of the seas’ principle and the notion that legitimate ships are sovereign territory. These norms and principles were globalized during the period of European expansion and imperialism, and were widely accepted by the 19^{th} century.

Nuclear Ocean: Strategic Stability, Ocean Opacity, and Nuclear-Armed Submarines

Between 1850 and 1950, the nature of naval power changed fundamentally. This period witnessed unprecedented growth in the number of military ships on the ocean, in addition to revolutionary change in ship technology, armaments, doctrine, strategy, and tactics.[492] As strategic and military use of the ocean expanded, customary international law and formal arms control agreements sought to shape military activities, in order to achieve the goal of peace (or at least reduce the risk of conflict). The 1856 Treaty of Paris, for example, established protections against seizure of neutral goods, or goods under neutral flags, in wartime. It also established that a "binding" blockade must be "effective" at preventing access to an enemy coast.[493] In the 1920s and 1930s, three multilateral naval arms limitation conferences sought to prevent a naval arms race by restricting the tonnage of particular types of ships in a ratio that maintained US and British naval hegemony.[494] These treaties failed to shape the nature and intensity of naval arms races and naval warfare, in large part because of their inability to account for technological change. The submarine and aircraft carrier became dominant naval warfare instruments in the first half of the twentieth century, undermining the assumptions of previous arms control treaties about the determinants of power on and under the ocean.

Naval arms control, like the ocean governance regime more generally, must contend with the particular geography, geophysics, and technology of the ocean. A particularly consequential and recent case study illustrates how the interaction between

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[492] Lincoln P. Paine, *The Sea and Civilization: A Maritime History of the World*, First Edition (New York: Knopf, 2013), 546.
[493] Ibid., 550.
[494] Ibid., 569.

the geophysical ocean and naval technologies plays a pivotal role in shaping one of the paramount world order arrangements in the post-World War II era. The regime of interest in this chapter is the world nuclear order, established after the advent of nuclear weapons to confront the obsolescence of territorial states as security providers. Because of the ever-present risk of nuclear destruction, the goal of the world nuclear order is peace through strategic stability. The choice of deterrence theory and strategy as a means to achieve strategic stability – described below – required the careful and coordinated management of naval forces on the part of the Cold War superpowers. The ocean itself, and its physical properties, interacts with technological capability to create a specific set of possibilities for regime success.

This chapter describes the relationship between strategic nuclear submarines, the world nuclear order, and the ocean governance regime. The first section unpacks the deterrence concept, and explains the choice of nuclear-armed submarines to bear the mantle of deterrence and thereby serve as the bulwark of strategic stability. The second section frames the Seabed Arms Control Treaty as an example of a particular approach to arms control, one that seeks to restrain technological systems and prevent the expansion of the nuclear arms race into new domains. The third section examines how the importance assigned to strategic nuclear submarines influenced the construction of the Law of the Sea Treaty. Each of these sections is a case of regime building, and this chapter demonstrates how in each case, the interaction between geography, geophysics, and technology shaped the content of the regime. The final section considers the effectiveness of the world nuclear order, given changes in technological capability and scientific knowledge of the maritime operational environment.

Strategic Nuclear Submarines

The development and detonation of atomic weaponry at the end of World War II so shocked established political and military thought that it can be accurately described as a 'Nuclear Revolution.' The expectation that nuclear weapons would continue to be used in conflict, and the emerging bipolar tension, stoked premonitions of eminent international disaster. Aversion to their continued use, combined with fear of giving them up, produced a period of contradiction and adjustment in the missions and strategies of the armed forces. A nuclear strategy was needed to reconcile the extreme strength and extreme vulnerability attendant to the Nuclear Revolution, and to find a use for apparently un-useable weapons. 'Deterrence theory' was meant to provide a practicable stopgap while more radical political solutions were formulated, but it was eventually fully incorporated into military doctrine, strategy, and force structure.[495] Deterrence theory relies on the idea that the threat of nuclear retaliation will prevent an enemy from starting a nuclear conflict. For deterrence to function, however, requires assurance that the victim of a 'first strike' will be able to respond after an initial attack. Thus, deterrence hinges on the maintenance of a 'secure second strike' capability that cannot be reliably eliminated in a disabling first strike. [496]

As land-based delivery vehicles became more targetable, military strategists sought ways to guarantee the ability to retaliate against a first strike. Although other means were pursued, such as hardened and mobile ballistic missiles and 'launch on warning' postures, nuclear-powered and nuclear-armed submarines (SSBNs) were

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[495] Jonathan Schell, *The Fate of the Earth, and, The Abolition*, Stanford Nuclear Age Series (Stanford, Calif: Stanford University Press, 2000).
[496] Robert Jervis, *The Meaning of the Nuclear Revolution: Statecraft and the Prospect of Armageddon* (Ithaca: Cornell University Press, 1989).

understood to be the most survivable, and therefore most reliable, secure second strike capability. In assuming the mantle of deterrence, they became a "keystone of global military strategy."[497] The ability of SSBNs and their ballistic missiles (SLBMs) to remain invulnerable to a nuclear first-strike is a function of their ability to hide beneath the surface of the ocean, which is opaque to most forms of surveillance.

The opacity of the ocean is a product of its unique features, which tend to thwart traditional surveillance technologies. Opacity varies over time, however, evolving with new scientific understandings of the operational environment and innovation in sensing and hiding technologies. Scientific study of the undersea environment helps illuminate where and how the 'signatures' of SSBNs can be detected. Advances in information technologies such as radar, sonar, and satellites allow users to locate and track objects of interest with increasing degrees of precision. Improvements in oceanographic modeling and computer processing assist in separating smaller and smaller signals from background noise. All of these innovations contribute to transparency. But science and technology have also produced increasingly sophisticated 'hiding' techniques and 'cloaking' technologies, which attempt to evade detection by reducing submarine signatures or enhancing background noise. These are means of rebuilding opacity. As science adds detail and precision to our understanding of the operational environment, and as technological innovations add to our capabilities to 'hide and seek,' ocean opacity may be subject to incremental erosions and/or sudden collapse as submarines become visible, and therefore targetable. Because the opacity of the submarine environment is

[497] H.D. Smith, "The Development and Management of the World Ocean," *Ocean & Coastal Management* 24 (1994): 7.

foundational for submarine-based strategic nuclear deterrence, its degradation entails serious potential volatility. This possibility is considered in detail in the final section.

The significance of ocean opacity for strategic nuclear stability implies that the basic condition of nuclear peace is a material one. Because scientific advancement and technological change continuously alter the relationship between transparency and opacity in the operational environment of nuclear forces, this basic condition cannot be understood as permanent. Transparency is a continuous variable that creates conditions of possibility for nuclear strategy. Transparency is typically understood to have benefits for political, economic, and social life.[498] In the security realm, transparency about intentions and capabilities discourages irrational wars and facilitates negotiated settlements.[499] Transparency in the location of nuclear forces, however, is more likely to be destabilizing insofar as it alters the incentives and vulnerabilities assumed by contemporary nuclear force structures. Most concerning for theories of nuclear deterrence are the conditions under which the 'secure second strike' remains secure, because invulnerability of some nuclear forces is thought to dis-incentivize a counter-force first strike. Indeed, many proponents of offense/defense theory suggest that secure second strike weapons, and in particular SLBMs, are functionally defensive and therefore help stabilize and pacify international politics.[500] The fabric of the international system in the nuclear era rests in large part on a particular premise about the interaction between technology and geography, which favors deterrence. Because of these high stakes, the conditions of

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[498] David Brin, *The Transparent Society: Will Technology Force Us to Choose between Privacy and Freedom?* (Reading, Mass.: Perseus Books, 1998); Ann Florini, *The Right to Know Transparency for an Open World* (New York: Columbia University Press, 2007); Micah L Sifry, *Wikileaks and the Age of Transparency*, 2011.
[499] Kristin M. Lord, *The Perils and Promise of Global Transparency: Why the Information Revolution May Not Lead to Security, Democracy, or Peace*, SUNY Series in Global Politics (Albany: State University of New York Press, 2006), 27.
[500] Michael E Brown et al., eds., *Offense, Defense, and War* (Cambridge, Mass.: MIT Press, 2004).

invulnerability, or survivability, remain an essential focus for theorists of nuclear peace, but are incomplete without careful examination of their fluid material foundations. The story begins in the early Cold War.

The 1960s were a significant decade for the maturation of the Cold War conflict. In the United States, calculations of qualitative and quantitative advance in Soviet nuclear forces, though often misguided, helped drive massive new expenditures on strategic nuclear weapons and delivery vehicles. The strategic nuclear 'triad' force structure emerged quickly, but was subject to upgrades and modifications throughout the Cold War. The 1960 deployment of Polaris-armed SSBNs by the United States represented a significant investment in invulnerable strike forces whose primary job was to maintain a credible threat of nuclear retaliation.[501] In 1961, the Polaris-armed SSBN was completely invulnerable to Soviet anti-submarine warfare (ASW). But the Soviet Union responded to Polaris with major new ASW programs, and although their success was limited, Navy and Department of Defense officials were seriously concerned about the potential of an ASW 'breakthrough.'[502] As the Cold War marched on, advances in weaponry and targeting made land-based nuclear delivery systems increasingly vulnerable to a counter-force first strike, which amplified the strategic importance of invulnerable SLBMs.[503]

The strategic studies literature has recognized the role of inter-service rivalry, perceptions of Soviet force structure, and the relationship between the Navy and oceanographers as partial explanations of why and how the US military shifted the mantle of 'mutually assured destruction' towards SSBNs. Because changes in the

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[501] Norman Polmar and Kenneth J Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines* (Washington, D.C.: Potomac Books, Inc., 2004), 167
[502] Ibid., 126, 185.
[503] Karl Lautenschlager, "The Submarine in Naval Warfare, 1901-2001," *International Security* 11, no. 3 (1986): 126, 130.

strategic balance, and perceptions of the strategic balance, are the result of numerous interconnected and overlapping factors, very few accounts capture the full detail of relevant Cold War history. Social and institutional explanations are incomplete insofar as they overlook the crucial relationship between the geophysical properties of a particular operational environment (ocean, atmosphere, or space) and the technology designed to operate there. The interaction between evolving technologies of sensing, hiding, and destroying and the growing knowledge of the ocean environment drove Cold War defense expenditures towards a submarine-centric strategic nuclear deterrent.

Shifting the Mantle of Deterrence

The most important feature of nuclear submarines was not that they could carry nuclear-tipped weaponry, but that they could do so without being located, targeted, and destroyed. The fact that SSBNs had this 'opacity advantage' over other nuclear forces was not determined by strategists, but was the outcome of rapid growth in the capabilities of surveillance technology. This revolution in transparency was driven by advances in existing sensing technologies (radar and sonar) and computer processing, and the development of new sensing platforms: surveillance aircraft and reconnaissance satellites.[504] It radically increased the vulnerability of land-based weapons systems and command and control centers to a disabling first strike. Although advances in transparency and targeting have been on going throughout military history, the shock of direct visual surveillance from air and space was highly concentrated during the early Cold War period. Transparency has major implications for force structure because it changes the value of existing weapons systems, such that the number and size of weapons

[504] Daniel Deudney, *Whole Earth Security: A Geopolitics of Peace* (Washington, D.C., USA: Worldwatch Institute, 1983), 6.

is no longer a reliable indicator of strength.[505] Even thousands of nuclear bombs and missiles cannot achieve credible retaliation if they can all be simultaneously located and destroyed. The increase in transparency during the early Cold War was so acute as to raise the specter of a debilitating or decapitating first strike whereby the enemy could prevent nuclear damage to itself, representing a serious challenge to deterrence-based strategy.

Transparency increases vulnerability by enabling better targeting. Specifically, the United States feared growing Soviet capabilities in ballistic missile accuracy and anti-ballistic missile (ABM) technology. These twin developments were seen as eroding the secure second strike from two sides, in that they made a first strike maximally destructive, and provided some defense against any second strike capabilities that might remain.[506] Although US nuclear-armed submarines could effectively hide from Soviet ASW during the early 1960s, strategists anticipated that this might change. Polaris-armed submarines were aging, and both Polaris and Poseidon missile systems had relatively limited ranges that constrained the size and location of patrol areas. The Americans believed that the incentives for a Soviet strike were growing, because the credibility of 'mutually assured destruction' was waning, and therefore in 1966 Secretary of Defense Robert McNamara commissioned the 'STRAT-X' study. The purpose of STRAT-X was to undertake a comprehensive analysis of nuclear force structure, in order to figure out how to maximize survivability in the event of a first strike scenario.[507] McNamara wanted specific investment proposals; executives from major defense contractors were involved,

[505] Ibid., 31.
[506] Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 183.
[507] Ibid., 183–84.

and each of the 124 projects surveyed had to be unique relative to existing platforms. The proposed projects "ranged from the sublime to the ridiculous," and included putting ICBMs in hardened subterranean silos, on trucks or railcars to make them mobile on land, on barges to make them mobile on existing or constructed waterways, on surface ships at sea, and on seabed platforms.[508] Many of the proposals came from an Air Force that knew its monopoly on the nuclear arsenal was threatened. Since 1960, the Air Force had considered multiple 'shell game' missile arrangements, the purpose of which was "to achieve invulnerability and deception by shifting the missiles among multiple silos."[509] Despite the fact that only two of the 124 proposals were sea-based, the final recommendations from the STRAT-X study included two land-based and two sea-based schemes. This balanced conclusion simply reflected inter-service politics, however, and the Navy's underwater long-range missile system (ULMS) was the only proposal eventually developed into the Trident missile system.[510] By the early 1970s, ULMS would become the agreed upon basis of mutual deterrence between the superpowers.[511]

Expectations of Opacity

The Navy's ULMS proposal was pursued for multiple reasons, but the most basic is the character of the maritime operational environment. The Navy was well prepared to argue in favor of submarine-launched ballistic missiles (SLBMs), because of its pre-

[508] D. D. Dalgleish and Larry Schweikart, *Trident*, Science and International Affairs Series (Carbondale: Southern Ill. Univ. Pr, 1984), 42.
[509] William F. Grover, *The President as Prisoner: A Structural Critique of the Carter and Reagan Years*, SUNY Series in the Presidency (Albany: State University of New York Press, 1989), 137.
[510] Dalgleish and Schweikart, *Trident*; Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 184.
[511] Thomas S Burns, *The Secret War for the Ocean Depths: Soviet-American Rivalry for Mastery of the Seas* (New York: Rawson Associates Publishers, 1978), 32.

existing, mutually beneficial, and productive relationship with oceanographers.[512] Proving that the SSBN concept was the most efficient and effective way to maintain credible retaliation throughout the period for which the STRAT-X study was commissioned (1975-85) required assessing the likelihood that the ocean would remain basically opaque in the face of technological innovation. The Navy had two decades of experience conducting research into the nature of the maritime operational environment, as part of the broad post-World War II effort to identify new strategic missions for the military services. Defining what naval forces, especially submarines, were capable of required basic oceanographic research. The characterization of the maritime environment received a major boost during the International Geophysical Year (1957-58), an international cooperative scientific effort "aimed to extend synoptic data collection over the entire Earth" and with a large number of projects focused on ocean properties.[513] The IGY was supposed to ease Cold War tensions, but one of the Soviet projects, the Sputnik satellite, signaled the potential for a major advancement in surveillance capabilities and catalyzed the search for new foundations of strategic deterrence.

The basic reason for the persistence of ocean opacity is a geophysical fact: only sound travels through ocean water in a way that is useful for long-range sensing technologies. Electro-magnetic radiation, and therefore radar, does not penetrate the ocean's surface well.[514] In other words, the atmosphere is transparent in a way that the ocean is not. Oceanographic labs and institutions working with the Navy characterized in detail what this geophysical reality meant for the possibilities of 'hiding' and 'seeking' in

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[512] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005).
[513] Ibid., 30.
[514] Deudney, *Whole Earth Security*, 26.

the ocean. In the late 1940s, oceanographers discovered natural sound channels that trapped and focused low frequency sound, suggesting the viability of passive acoustic sensing via arrays of sonar hydrophones.[515] In the course of investigating the acoustic environment in the North Atlantic and around important sea lines of communication, the significance of thermal layering, depth, and seafloor terrain for obstructing and distorting sound propagation became clearer.[516] Oceanographers also described and characterized the sources and nature of ocean background 'noise,' a critical step in defining the signal-to-noise ratio that ultimately determines the acoustic visibility of submarines. Because these geographical and geophysical features of the ocean determined the possibilities and obstacles for acoustic sensing, oceanographic data, especially bathymetric charts and bathythermograph data, were subject to security classification; "oceanographic data presented a case in which basic science itself was a commodity of extreme importance to the Navy's operations."[517] This accumulated knowledge about the oceanic operational environment led military strategists to conclude that the advantage of SSBNs over ASW would persist in the face of technological innovation. The acoustic sensing technologies best suited to the hydrosphere had limited range and could be easily thwarted with defensive technology.

Investments in Transparency

Submarines became the foundation of nuclear deterrence because passive acoustic sensing could not make the ocean fully transparent, but the superpowers still invested in detection technologies. The Soviet Union deployed its first nuclear-armed submarines in

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[515] Owen R. Jr. Cote, "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines," 2000.
[516] Hamblin, *Oceanographers and the Cold War*, 40–41.
[517] Ibid., 56.

1968, and despite a pre-existing "tremendous acoustic advantage" the United States wanted to maximize the chances of tracking them.[518] The first major projects were

[518] Cote, "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet

Submarines."

passive sonar arrays, linked by radio or submarine cable to centralized computer processing centers that would separate the 'signal' from the 'noise.' Referred to as 'SOSUS' (Sound Surveillance System), these hydrophones placed along undersea cables were extensive enough to detect very low frequency signals, which propagate farther than high frequencies. By 1958, the United States had SOSUS systems along the entire eastern seaboard, in Hawaii, and along parts of the Pacific seaboard. By 1965, a network of passive acoustic hydrophones spanned the 'GIUK' gap, which served as a primary means of egress for Soviet submarines entering open ocean patrol areas. By the 1970s there were over 20 SOSUS installations at global strategic locations, including important chokepoints such as the Straits of Gibraltar. This regional acoustic detection strategy was combined with a ‘coordinated ASW’ response that included surface ships and surveillance aircraft utilizing active sonar and radar on the surface of the ocean. Although

Figure 10 - GIUK gap, From Fischer, Benjamin B. A Cold War Conundrum: The 1983 Soviet War Scare. Central Intelligence Agency, Center for the Study of Intelligence, 1997.

active sonar is more effective at localization, it has a shorter range and reveals the presence of a seeker, and was generally eschewed by US submarines during the Cold War, in favor of passive acoustic sensing.[519]

[519] Tom Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy* (Lexington, Mass: Lexington Books, 1987), 217–18; Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 149.

The Soviet Union also invested in passive sonar arrays, although they were inferior to SOSUS.[520] Upon realizing their vulnerability to detection in the open ocean, in the mid-1970s Soviet SSBNs adopted a 'bastion' strategy whereby they remained in the "marginal ice seas of the Soviet Arctic littoral," avoiding traversal of the SOSUS arrays but keeping SLBMs within strike range of the United States.[521] This hiding strategy was possible because of the long range of SLBMs, and because any attack on Russian SSBNs was expected to come from US attack submarines.[522] The bastion strategy partially redressed Soviet submarine vulnerability by creating a zone of "active defense" in which detection was possible, but localization required risky transit into the heavily defended and Soviet-controlled Barents Sea.[523]

Internal Arms Racing

It is easy to overlook the essential stability of ocean opacity throughout the Cold War. Investments in both hiding and detection produced incremental advances in both capabilities for decades. This technological arms race was driven by more than just competition between the hiding Soviet Union and the seeking United States; it continued largely because of the institutional structures in which it was embedded. The US military regularly produced reports detailing expected innovations in Soviet technology, and therefore improvements in Soviet capability. A lack of reliable intelligence led the Americans to imagine 'worst case scenarios' that drove reactive investments. Because the tasks of detection and concealment were contracted out to different labs and research institutions, internal competition increased the budgets for both. Improvements in passive

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[520] Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 186.
[521] Cote, "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines."
[522] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 7.
[523] Ibid.

acoustic sensing technology, especially SOSUS, pushed American submarine designers to build quieter submarines. This "technical competition between listeners and hiders," all occurring within US research institutions, drove American submarine and ASW technology forward in what was perceived as a race with the Soviets, but is more accurately understood as an internal race.[524] Yearly ASW exercises in the 1960s generated performance analyses that were used to justify defense expenditures to fill 'gaps' in capabilities. Despite this dynamism in technological capability, nuclear deterrence remained stable because of the opportunities for hiding provided by the ocean environment.

Cold War Opacity

Because passive sonar relied on submarines making noise, both sides pursued quieting in vessel design and operation. Nuclear power was the first major design innovation for the purposes of concealment, because it decreased the need to surface regularly. The previous classes of diesel-electric submarines had to surface or snorkel periodically to recharge their batteries, making them vulnerable to multiple modes of detection. But the first generation of nuclear submarines was also constantly noisy, as opposed to the intermittent loudness of diesel electric submarines.[525] Even a stopped nuclear submarine generates noise from its power plant, whereas a submarine running on only electric power is very quiet.[526] Despite this, US nuclear submarines maintained opacity throughout the Cold War through hiding techniques that reduced acoustic signatures or created decoy signals. The United States developed nuclear-powered

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[524] Cote, "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines."
[525] Ibid., 21.
[526] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 9.

submarines first, and designed their internal parts to be quieter; the Polaris-armed submarines deployed in the 1960s "were superior in all respects to contemporary Soviet ballistic missile submarines."[527] The shape of submarine hulls was contoured to reduce the active sonar signature, and operators used hiding techniques like slow speeds, limited communications, and travel below the thermocline. Both superpowers invested in decoys and noisemakers, which could multiply the number of apparently valid targets, or even eliminate the possibility of acoustic detection altogether.[528] During the Cold War, maintenance of ocean opacity was assured by continued innovations in concealment technologies.

The United States maintained a "unique and enduring advantage" in passive acoustics throughout the Cold War, but even the most optimistic assessments of its 'seeking' capabilities do not conclude that Soviet SSBNs could be located and targeted with enough certainty to incentivize a US first strike.[529] And eventually Soviet submarines began to get quieter. Investment in 'hiding' technologies may have been accelerated by intelligence about SOSUS sold to the Soviets by U.S. Navy Chief Warrant Officer John A. Walker, who leaked naval secrets from 1967-85.[530] The maturation of Soviet quieting technologies in the early 1980s appeared as bipolar convergence on an 'opacity advantage,' leading one US Admiral to predict that "at some point, nobody will

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[527] Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 167.

[528] Richard L. Garwin, "Will Strategic Submarines Be Vulnerable?," *International Security* 8, no. 2 (Fall 1983): 59–60; Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 284.

[529] Austin Long and Brendan Rittenhouse Green, "Stalking the Secure Second Strike: Intelligence, Counterforce, and Nuclear Strategy," *Journal of Strategic Studies* 38, no. 1–2 (January 2, 2015): 38–73.; R.B. Byers, "Seapower, Nuclear Weapons and Arms Control," in *The Denuclearisation of the Oceans*, ed. R.B. Byers (New York: St. Martin's Press, 1986), 172.

[530] Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 285.

be able to find a submarine with anything."[531] Official Navy reports expressed confidence in the persistent advantage of 'hiding' over 'seeking' technologies (which were really mostly 'listening'), and took for granted the resilience of strategic invulnerability in the face of technological innovation.[532] When a Russian official conveyed his confidence in 1992 that space-based radar and optical detection systems were five to ten years away from achieving strategic transparency, US scientists expressed strong skepticism.[533] Despite this confidence in opacity, the US Air Force continued proposing alternative basing schemes, including in deep space, in an effort to reclaim part of the mantle of 'mutually assured destruction.'[534] Instead of pursuing alternative schemes for opacity, the US military augmented the SOSUS system in the mid-1980s, adding surveillance ships towing sonar arrays hundreds of meters long. Information from SOSUS and towed arrays were processed together, and became known as the Integrated Undersea Surveillance System. Despite these minor improvements in sensing technology, 'hiding' had the advantage on both sides when the Cold War ended, and the secure second strike was therefore assured.

Seabed Arms Control Treaty

The invulnerability of SSBNs during the Cold War created an opportunity for arms control in the ocean: the Seabed Arms Control Treaty (or 'Seabed Treaty'). In the

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[531] Cote, "The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines."
[532] Garwin, "Will Strategic Submarines Be Vulnerable?," 63; Lautenschlager, "The Submarine in Naval Warfare, 1901-2001," 132.
[533] Polmar and Moore, *Cold War Submarines the Design and Construction of U.S. and Soviet Submarines*, 186.
[534] "Design and Construction of Deep Underground Basing Facilities for Strategic Missiles: Briefing on System Concepts and Requirements," Workshop Conducted by the U.S. National Committee on Tunneling Technology, Commission on Engineering and Technical Systems (National Research Council, 1982); Robert H. Chisholm, "On Space Warfare: Military Strategy for Space Operations" (Maxwell Air Force Base, Alabama: Airpower Research Institute, June 1984)

mid-1960s, commercial and scientific groups began exploring and contemplating the seabed with increased focus and vigor. A variety of ambitious plans for using the deep sea and seabed were proposed.[535] Reports began circulating about military plans for the deep ocean, prompting concerns about the possibility of a new phase of the nuclear arms race.[536] Both superpowers had indeed contemplated basing weapons on the seafloor, including nuclear-tipped ICBMs, nuclear-armed 'crawlers,' and nuclear-armed mines.[537] These schemes would take advantage of the ocean opacity that made nuclear forces harder to locate, and "even if their exact location were known they would be more difficult to neutralize."[538] Although basing nuclear weapons on the sea floor was genuinely contemplated, the superpowers instead decided to pledge mutual restraint.

Restraining Technology

The Seabed Treaty, which entered into force in 1972, committed its members "not to emplant or emplace on the seabed…any nuclear weapons or any other types of weapons of mass destruction." The origins of the Seabed Treaty can be found in a 1967 speech given by Arvid Pardo, the Maltese representative to the United Nations, which declared that the seabed was the "common heritage of mankind."[539] In addition to this general idea about reserving the seabed for peaceful uses, the superpowers had their own reasons for outlawing the basing of nuclear weapons on or under the seabed. The United

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535 A. Meerburg and E. Myjer, "The Sea-Bed Treaty: Some General Observations," *Disarmament: A Periodic Review by the United Nations* VI, no. 2 (Summer 1983): 73–76.
536 Bennett Ramberg, "Tactical Advantages of Opening Positioning Strategies: Lessons from the Seabed Arms Control Talks 1967-1970," *The Journal of Conflict Resolution* 21, no. 4 (December 1977): 691.
537 Ibid., 692; Meerburg and Myjer, "The Sea-Bed Treaty: Some General Observations," 76.; James A. Barry, "Seabed Arms Control Issue, 1967-1971: A Superpower Symbiosis?," *International Law Studies* 61 (1980): 576.; Ann L Hollick, *U.S. Foreign Policy and the Law of the Sea* (Princeton, N.J.: Princeton University Press, 1981), 184–85.
538 Meerburg and Myjer, "The Sea-Bed Treaty: Some General Observations," 76.
539 Elisabeth Mann Borgese, "The Sea-Bed Treaty and the Law of the Sea: Prospects for Harmonisation," in *The Denuclearisation of the Oceans*, ed. R.B. Byers (New York: St. Martin's Press, 1986), 88; Ramberg, "Tactical Advantages of Opening Positioning Strategies: Lessons from the Seabed Arms Control Talks 1967-1970," 691.

States and Soviet Union recognized that the Cold War rivalry had a kind of technological momentum, whereby advances in technology were producing violence capabilities unrelated to actual political and strategic goals. The "momentum of technology" was understood as potentially very dangerous, and tremendously expensive.[540] The Seabed Treaty provided a bulwark against new and frivolous weapons systems, by giving both governments "a legal excuse for saying no to [their] military-industrial lobbyists."[541]

Despite this superpower consensus, there was some negotiation over the terms of the Seabed Treaty. The Soviet Union proposed to fully 'de-militarize' the seabed, which would prohibit the emplacement of SOSUS hydrophones, among other things. The United States wanted the nuclear-free zone to end 3 miles from the coastline, whereas the Soviets preferred allowing emplacement within a 12-mile zone. After exchanging draft treaties, both states compromised rather quickly. The final Treaty only prohibits weapons of mass destruction, a concession to the United States, and does so only up to 12 miles from the coastline, a concession to the Soviet Union.[542] The biggest challenge to reaching agreement was actually the problem of verification.[543] Most countries wanted some form of internationalized verification, while the superpowers were content without designating a special procedure or new authority.[544] Article III of the Seabed Treaty represents a compromise on the question of verification, by giving each state the right to verify on its own, but also providing the opportunity to refer the issue to the United Nations Security Council.

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[540] Barry, "Seabed Arms Control Issue, 1967-1971: A Superpower Symbiosis?," 575.
[541] Ibid., 583.
[542] Barry, "Seabed Arms Control Issue, 1967-1971: A Superpower Symbiosis?," 579.
[543] Jozef Goldblat, "The Sea-Bed Treaty: Its History, Scope, Verification and Implementation," *Disarmament: A Periodic Review by the United Nations* VI, no. 2 (Summer 1983): 57.
[544] Borgese, "The Sea-Bed Treaty and the Law of the Sea: Prospects for Harmonisation," 92.

The Seabed Treaty and SOSUS

The Seabed Treaty might be understood as a missed opportunity for ensuring the invulnerability of US and Soviet SSBNs, and therefore strengthening the foundations of deterrence. During the 1960s and 1970s, US submarine detection primarily relied on hydrophones placed on the seabed. If that ASW capability became too effective and made detection and localization possible, the likely result would be strategic instability. For this reason, the Soviet proposal to de-militarize the seabed may have been "stabilizing in the long run, since it would have brought the survivability of the Soviet ballistic missile submarine force to a level equal to that of our POLARIS force, thus giving both sides an assured destruction capability."[545] There are four basic reasons the de-militarization approach was rejected in favor of de-nuclearization.

First – de-militarization would have been a major shift in strategic advantage from the United States to the Soviet Union. At the time of negotiation, western ASW technology was more advanced than similar Soviet systems. The United States and its allies also had a durable geographic advantage in ASW, given their control of important chokepoints like the GIUK gap, and the favorable acoustic environment of the Barents Sea. And without ASW capabilities, geography would make US allies more vulnerable, because they were "far more dependent on the sea for bringing in reinforcements in a crisis," compared to the Soviet Union.[546] So the United States opposed de-militarization because it would provide the Soviet Union "an important military advantage with little or nothing in exchange."[547]

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[545] Barry, "Seabed Arms Control Issue, 1967-1971: A Superpower Symbiosis?," 583; Eric P.J. Myjer, "The Law of Disarmament and Arms Control: Implications for the Law of the Sea," in *The Denuclearisation of the Oceans*, ed. R.B. Byers (New York: St. Martin's Press, 1986), 114.
[546] Meerburg and Myjer, "The Sea-Bed Treaty: Some General Observations," 75.
[547] Ibid.

Second – the Soviet Union had its own interest in maintaining the possibility of conventional militarization of the seabed. Restricting the Seabed Treaty to de-nuclearization ensured that the ocean floor was "preserved as an extensive area of military potential." [548] The Soviet Union, United States, and other countries recognized the future potential of the deep ocean and seabed as a test range for underwater weapons. They also envisioned underwater bases for submarine repair, command and control, or protection of commercial endeavors. Although expectations of nuclear basing on the sea floor provoked trepidation, the idea of conventional militarization was "exciting" for many states.[549] With a de-nuclearization approach, the superpowers could preserve the seabed, and potentially arm it too.

Third – the ASW capabilities that made Soviet SSBNs vulnerable to detection had utility for other "general-purpose naval missions."[550] So while banning ASW systems on the seafloor might protect the second strike capability of SSBNs (particularly Soviet SSBNs), it would also have a detrimental effect on other maritime capabilities. The most significant loss would have been the ability to detect conventional attack submarines, which threaten surface vessels and also provide a means of attack against SSBNs.[551]

Fourth – as US Ambassador Gerard Smith regularly pointed out, complete de-militarization would be a significant, potentially insurmountable, challenge for verification. Placing a weapon of mass destruction on the seafloor would be fairly noticeable, given the massive infrastructure requirements. In contrast, many objects with utility to the military are small and easy to place clandestinely. And because many seabed

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[548] Ibid., 77-79.
[549] Ibid., 75.
[550] Myjer, "The Law of Disarmament and Arms Control: Implications for the Law of the Sea," 183.
[551] Meerburg and Myjer, "The Sea-Bed Treaty: Some General Observations," 75.

technologies are dual use, complete de-militarization would necessitate the complex and burdensome task of "deciding whether each object or installation emplaced on the sea-bed was of a military nature."[552]

Spatial Arms Control

The Seabed Arms Control Treaty is an example of a particular type of arms control developed during the Cold War, and applied to non-terrestrial spaces. Before and after negotiations, the United States drew an explicit comparison to the Outer Space Treaty of 1967.[553] US negotiators noted that the Outer Space Treaty specifically bans nuclear weapons and weapons of mass destruction, instead of broad de-militarization.[554] In both treaties, an emerging new area of human activity was closed off to the possibility of nuclear weapons basing, before that basing was actually pursued. As additions to the world nuclear order, the Outer Space and Seabed Treaties are examples of restraint, instead of relinquishment. And that restraint is based on spatial areas, not specific technologies. Instead of banning or regulating the number and size of weapons systems, as in the failed interwar naval arms limitation agreements, these treaties prevent nuclear rivalry and arms racing from expanding into new domains. According to the United States federal government, the idea was to "prevent an arms race before it had the chance to start," and to "preserve this new seabed environment for the benefit of mankind."[555]

Negotiation of the Seabed Treaty was relatively easy because of the reliability and invulnerability of SSBNs, and specifically because of their superiority to seabed-based

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[552] Jozef Goldblat, "The Sea-Bed Treaty: Its History, Scope, Verification and Implementation," *Disarmament: A Periodic Review by the United Nations* VI, no. 2 (Summer 1983): 56.
[553] John N. Irwin II, "Department Urges Senate Approval of Seabed Arms Control Treaty," *Department of State Bulletin* 66 (1972): 312.
[554] Goldblat, "The Sea-Bed Treaty: Its History, Scope, Verification and Implementation," 55.
[555] Damien J. LaVera and Thomas Graham, *Cornerstones of Security: Arms Control Treaties in the Nuclear Era* (University of Washington Press, 2003), 283; Irwin II, "Department Urges Senate Approval of Seabed Arms Control Treaty."

nuclear weapons systems. SSBNs were more likely to avoid detection because of their mobility.[556] Although the proposed nuclear 'crawlers' would have been mobile, even in the best-case scenario they would be slow, and obstructed by topographic obstacles on the sea floor. And SSBNs were an established technology, with decades of research and development. Over the course of the 1960s, optimism was replaced with the idea that seabed based weapons were a "technological blind alley." [557] Because the cost of seabed-based nuclear weapons systems would be exorbitant, and because SSBNs already provided assurance of nuclear retaliation in the event of a first strike, the attitude of the superpowers to placing nuclear weapons on the seafloor was simple and straightforward: "why bother?"[558]

Law of International Straits

In the 1970s, the ability of SSBNs to remain undetected became of subject of political and legal contention. The Third United Nations Convention on the Law of the Sea (UNCLOS) convened in 1973, with the goal of negotiating a 'Constitution for the Oceans' that covered multiple ocean uses. While UNCLOS specifically set aside military matters like arms control, laws relating to transit had the potential to affect military activities. In regards to SSBNs, determinations about the width of the territorial sea and the status of international straits had the potential to inhibit submarine navigation. In the two decades before UNCLOS, the norm of the 3-mile territorial sea had been undermined and challenged by a series of unilateral claims to a 12-mile territorial sea. If the 12-mile territorial sea became enshrined in international law, 116 international straits (those used widely and regularly by the international community) would be composed entirely of

[556] Goldblat, "The Sea-Bed Treaty: Its History, Scope, Verification and Implementation," 63.
[557] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 186.
[558] Meerburg and Myjer, "The Sea-Bed Treaty: Some General Observations," 76.

territorial waters. A previous international agreement, the 1958 Geneva Convention on the Territorial Sea and the Contiguous Zone, had established that transit through territorial waters is subject to 'innocent passage,' and therefore requires submarines to "navigate on the surface and to show their flag" (Article 14). But at the time of this agreement, the 3-mile territorial sea was still the norm, and therefore most international straits contained a 'high seas corridor' through which submarines could pass submerged.[559]

In the early years of the UNCLOS negotiations (1973-1982), a coalition of 'straits states' (Cyprus, Greece, Indonesia, Morocco, Spain, and Yemen) proposed that submarines be required to give prior notice, receive prior authorization, and travel through straits on the surface and showing their flag.[560] The US Navy strongly opposed this blueprint for the international straits regime, because the requirements "would make it easier for an antagonist to locate and, thereby, threaten the submarines."[561] The result would undermine strategic stability, because of the increased vulnerability of SSBNs when they surface, and because neither superpower could trust that the other was fully complying with the surfacing requirement. A secondary concern related to navigational safety. SSBNs are designed to travel submerged, and when traveling on the surface they have a dangerously low profile and are less maneuverable. In a chokepoint of global shipping traffic, traveling on the surface would greatly increase the risk of collision.[562]

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[559] Ronald I. Clove, "Submarine Navigation in International Straits: A Legal Perspective," *Naval Law Review* 39 (1990): 106.
[560] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 294.
[561] Mark W. Janis, *Sea Power and the Law of the Sea*, Studies in Marine Affairs (Lexington, Mass: Lexington Books, 1976), 5.
[562] Clove, "Submarine Navigation in International Straits: A Legal Perspective," 107.

The US Navy won its preferred outcome in the final treaty, in part because the Soviet Union and Great Britain supported the US position. The United States also eventually made concessions related to the territorial sea and seabed mining, in order to win support for its free passage agenda. Article 39 of UNCLOS defines ‘transit passage’ through international straits, which allows ships and submarines to maintain their “normal modes of continuous and expeditious transit.” Although the United States never ratified UNCLOS, the norm of submerged transit through international straits has achieved the status of customary international law.[563]

Interestingly, none of this may have mattered for the security of SSBNs. A 1974 study by Robert E. Osgood reviewed all the world’s international straits to determine how the US Navy’s capabilities would change under the ‘innocent passage’ regime proposed by the straits states.[564] Out of only 16 straits that might be important for SSBN passage, all except three have convenient alternative routes. And friendly governments controlled the three straits that must be transited – Ombai-Wetar and Lombok in Indonesia, and Gibraltar at the entrance to the Mediterranean. Apart from these three straits, “passage through straits is not vital for the United States Navy.”[565] But the supreme importance attached to SSBN invulnerability, combined with the risk that friendly governments might become unfriendly, meant that the US Navy was unwilling to budge on its preferred regime for international straits.[566] Technologically and legally, the invulnerability of SSBNs was assured throughout the Cold War.

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[563] Ibid., 105, 108.
[564] Robert E. Osgood, “U.S. Security Interests in Ocean Law,” *Ocean Development & International Law* 2, no. 1 (1974): 1–36.
[565] Janis, *Sea Power and the Law of the Sea*, 7.
[566] Ibid., 5.

Erosion of Opacity

Confidence in the persistent advantage of SSBNs over ASW has, since the end of the Cold War, co-existed with warnings about the specter of ocean transparency. But technological advances have only recently made the expectation of transparency truly compelling.[567] The momentum of a broad-based and well-funded effort to discover and document the oceans has produced new scientific understanding and technology, and overcome key barriers to Cold War ocean sensing like limited platform penetration and slow data processing.[568] In particular, new maps of the operational environmental help separate the signal from the noise. New motivations have engaged industry in the process of developing enabling technologies. And continued improvements in acoustic sensing are joined by innovations in non-acoustic sensing. Oceanographers speak breathlessly of being "poised on the brink of a series of improvements" from "transformational technologies" that will facilitate "truly synoptic observations of ocean regions and processes."[569] The accelerating pace of technological change carries risks, however, and may nullify the utility of SSBNs for strategic nuclear deterrence as new sensors and platforms make the ocean increasingly transparent.[570] This section assesses and supports the claim that technological innovations will spread across the ocean in the next few decades and achieve an unprecedented degree of transparency.[571] Before examining how

[567] Paul Ingram, "Trident: The Need for a Comprehensive Risk Assessment," Short policy brief (BASIC, November 23, 2015); Paul Ingram, "Will Trident Still Work in the Future?," Short policy brief (BASIC, January 22, 2016).
[568] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*.
[569] Deborah Ann Glickson et al., eds., *Oceanography in 2025: Proceedings of a Workshop* (Washington, D.C: National Academies Press, 2009), 93, 21, 41.
[570] Ingram, "Will Trident Still Work in the Future?," 3.
[571] James Clay Moltz, "Submarine and Autonomous Vessel Proliferation: Implications for Future Strategic Stability at Sea," Project on Advanced Systems and Concepts for Countering WMD (U.S. Naval Postgraduate School Center on Contemporary Conflict, December 2012), 18.; Bryan Clark, "The Emerging Era in Undersea Warfare," Studies (Center for Budgetary and Strategic Analysis, January 22, 2015), 8.

transparency might be achieved, it is important to understand why crossing this threshold is increasingly likely.

New Motivations

The end of the Cold War marked the decline of a major driver of investment in submarine hiding and seeking technologies. In the last two decades, a powerful new motivation for understanding and monitoring the ocean has materialized: climate change. The urgency and shared vulnerability of this planetary problem demands tremendous investment in redressing gaps in our knowledge of atmosphere-ocean interactions. Especially relevant are the details of carbon and heat storage, the dynamics of thermohaline circulation, and the effects of ocean acidification on marine ecosystems. Much of this data is dual use; for example, measuring changes in stratification and mixing in the water column informs scientists about the effects of global warming on ocean circulation, and submariners about the likely pathways for sound propagation. Increasingly precise measurements of sea surface height help characterize regional variation in sea level rise, but could also potentially be capable of detecting the wakes of passing submarines.

Because oceanography is an 'observational science,' marine scientists prioritize increasing, diversifying, and achieving a higher resolution for the data flows coming from the ocean.[572] This entails the establishment of coordinated observation programs that address the need for data at larger and longer scales by deploying floating, steered, and *in situ* sensing platforms.[573] Autonomous drones on and under the surface are being tested

[572] Glickson et al., *Oceanography in 2025*, 51, 59.
[573] Glickson et al., *Oceanography in 2025*; Henry A. Ruhl et al., "Societal Need for Improved Understanding of Climate Change, Anthropogenic Impacts, and Geo-Hazard Warning Drive Development of Ocean Observatories in European Seas," *Progress in Oceanography* 91, no. 1 (October 2011): 1–33.;

and deployed to gather scientific data throughout the ocean.[574] Operators of these sensory arrays describe what they are doing as "essentially providing an extension of the internet over the oceans."[575] A participant in the National Research Council's workshop *Oceanography in 2025* described the discipline's essential aim: "our goal is to make the ocean as transparent as possible."[576]

The breadth and depth of scientific effort makes civilian and government oceanographers an independent strategic force in the technological balance between opacity and transparency, a new constituency with strong motivations to discover, detail, and document ocean processes. Their open access model for data sharing helps redress funding shortfalls and geographic limitations, and represents a reversal of the Cold War practice of classifying oceanographic data. This effort contributes to the detection of SSBNs because sensing technology is dual use, but also because the improved scientific understanding of the ocean makes it easier for sensors to distinguish the signal from the noise.

New Maps

As the ocean becomes increasingly "sensor rich," new types and quantities of data are producing a more detailed picture of the ocean.[577] Cold War era maps and models were so rife with assumptions and elisions that they are best understood as "works of

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Russell B. Wynn et al., "Autonomous Underwater Vehicles (AUVs): Their Past, Present and Future Contributions to the Advancement of Marine Geoscience," *Marine Geology* 352 (June 2014): 451–68.
[574] John Markoff, "No Sailors Needed: Robot Sailboats Scour the Oceans for Data," *The New York Times*, September 4, 2016
[575] Denise Deveau, "Big Data to Help Keep Fresh Water Clean, Manage Waste and Detect Tsunamis," *Financial Post*, September 10, 2014.
[576] Glickson et al., *Oceanography in 2025*, 154.
[577] David Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare," Parliamentary Briefings on Trident Renewal (BASIC, March 2016).

extrapolation, interpolation and inspiration, not mere measurement."[578] Oceanographers are now deploying advanced sensory networks to refine these maps by providing more of the necessary information to create accurate representations. In particular, advances have been made in mapping the topography and composition of the sea floor. The integration of GPS satellites has improved the precision of acoustic data collection, and new understandings of the 'deep scattering layer' minimize inaccurate soundings. But the requirement of using surface vessels still limits the range of sonar bathymetry. Since the 1990s, satellite radar altimetry has been used to produce wider area measurements of several sea surface properties, from which oceanographers can glean information about the seabed.[579] In 2014, the first new map of the ocean floor in twenty years was produced from satellite altimetry data, and it was twice as accurate as the last one.[580] This map is open access, available on Google Earth. The refinement of such maps matters for submarine detection because the contours of the seabed strongly condition and obstruct sound propagation, so that better maps improve acoustic detection techniques. This kind of basic knowledge about the physical ocean is "the foundation of all ASW objectives."[581]

Enabling Technologies

The complexity and variability of the ocean environment vastly increases the computational requirements of separating the signal from the noise.[582] Since the Cold War, advances in digital processing, solid state memory, and lithium batteries have

578 "The See-Through Sea," *The Economist*, June 7, 2016.
579 Ibid.
580 Scott Sutherland, "Thousands of Undersea Mountains Unveiled as New Gravity Map Strips Away Earth's Oceans," *The Weather Network*, October 20, 2014.
581 Stephen J. Coughlin, "Reclaiming Antisubmarine Dominance," *U.S. Naval Institute Proceedings* 139, no. 1 (January 2013): 40–45.
582 Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 13.

increased computational power while decreasing computer size.[583] These technologies enable small sensing platforms to process information *in situ*, and communicate and coordinate across multiple platforms, allowing them to operate as a 'swarm.' Scientists are currently testing the use of artificial intelligence software to increase the autonomy and integration of the swarm.[584] Operation as a network will enhance the potency of sensors, especially when they are mobile and can automatically optimize their behavior or position.[585] But exploitation of these possibilities requires a new generation of platforms, because Cold War vehicles are too large and expensive to effectively operate in a large and mobile network. Aerial, surface, and submarine drone technology satisfies the need for this capability.

A major obstacle to ocean transparency during the Cold War was the persistent gap between detection of a submarine and the localization required for effective targeting. The relative ease of detection using static acoustic platforms preceded the more difficult task of localization using mobile platforms. Autonomous Underwater Vehicles (AUVs) or 'drones' can collapse the spatial and temporal distances between detection and localization. When contemporary AUVs are widely distributed, equipped with effective short-range sensors, and networked together, "detection and localization will be simultaneous."[586] With large numbers of drones, the location of an SSBN is 'compromised' all at once – the idea is that detection by one AUV automatically triggers

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583 Glickson et al., *Oceanography in 2025*, 36.
584 Lonny Lippsett, "A Robot Starts to Make Decisions on Its Own.," *Oceanus* 48, no. 1 (June 2010): 28–29.
585 Carlo Kopp, "Evolving ASW Sensor Technology," *Defence Today*, December 2010, 26; D.T. Hughes et al., "Collaborative Multistatic ASW Using AUVS: Demonstrating Necessary Technologies" (MAST, Stockholm, Sweden: NATO Undersea Research Centre., 2009), 1.
586 Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 5.

the others to swarm together in pursuit, calculating the target's trajectory in real time.[587] These drones can carry any type of sensor including towed passive arrays, and operate in risky maritime environments (because they are relatively cheap and unmanned).[588] They could also potentially operate as weapons delivery platforms, or kamikazes, although the primary ASW missions envisioned for AUVs do not include weapons engagement.[589] Enabling drones to track targets automatically complicates countermeasures like evasive maneuvering, deep diving, and the use of decoys. If the full suite of small, autonomous sensing platforms is developed as planned, the outcome is likely to be "highly disruptive" for the existing balance between hiding and seeking.[590] The degree of transparency this scenario represents would be unprecedented, and is currently within the realm of technological possibility.

AUVs are still an emerging technology, but the commercial, scientific, and military sectors are all investing in research and development. Networked underwater drones represent a superior, and potentially cheaper, means of mapping and monitoring the ocean environment. Because AUVs are seen as a major growth market, companies that design sensors, communications, power sources, and vessels are increasingly involved in developing specialized versions of these technologies.[591] In the commercial sector, AUVs produce detailed maps of the seafloor in order to identify the best locations for offshore drilling, deep seabed mining, and the position of submarine telecommunications cables. Once operations are underway, AUVs can inspect and

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[587] Ingram, "Trident: The Need for a Comprehensive Risk Assessment," 2.
[588] David Blagden, "What DARPA's Naval Drone Could Mean for the Balance of Power," *War on the Rocks*, July 9, 2015; Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare."
[589] Robert W. Button et al., *A Survey of Missions for Unmanned Undersea Vehicles*, RAND Corporation Monograph Series (Santa Monica, CA: RAND, 2009), 20; Andrew Krepinevich, "Maritime Competition in a Mature Precision-Strike Regime" (Center for Budgetary and Strategic Analysis, 2014).
[590] Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare."
[591] J.R. Wilson, "UUVs Hit Their Stride," *Military & Aerospace Electronics*, April 2016, 19–20.

monitor technological systems and assist in making repairs. For oceanographers, AUVs are an important new tool for exploring hydrothermal vents, toxic cold seeps, and other benthic marine habitats. Some underwater drones can already operate to a depth of 6000 meters and adapt to unexpected conditions, but advancements in their endurance and flexibility are still anticipated.[592] In particular, marine scientists are developing underwater gliders that rely on buoyancy engines, "a slow but frugal form of travel with a tiny power requirement."[593] These gliders can travel long distances over months, and oceanographers use them to collect large-scale data on chemical and geophysical properties of the ocean. Gliders have also been used to measure radiation levels, inspect icebergs and submarine volcanoes, and follow whales. They have significant dual use potential, especially because gliders are extremely quiet, which makes the acoustic sensors they carry more effective. The Chinese in particular are developing the "academic base" for this technology, although US defense contractors lead in the production of diverse prototypes.[594]

The United States military has invested in several different types of drone programs. The P-8 Poseidon surveillance plane is currently equipped to release Coyote drones from the same tubes used to deploy sonar buoys. Although their mission time is limited to 90 minutes, these aerial drones can be recovered and reused.[595] The Defense Advanced Research Projects Agency's (DARPA) 'Upward Falling Payload' program envisions pre-positioned nodes concealed on the vast seabed, which can be activated and deployed immediately. The current design releases payloads that float to the surface and

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592 Wynn et al., "Autonomous Underwater Vehicles (AUVs)."
593 Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare," 5.
594 Ibid., 5–8; Wilson, "UUVs Hit Their Stride."
595 Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare."

deploy aerial drones.[596] In terms of underwater drones, the Navy has for some time used small, remotely operated vehicles for search and rescue and minesweeping operations.[597] A new autonomous drone, the Large Displacement Unmanned Underwater Vehicle, represents a significant advance. Designed for intelligence and surveillance, this small system will be "stowed, launched and recovered by multiple-host platforms," including ships, attack submarines, and SSBNs.[598] Finally, DARPA's autonomous surface vessel – the Anti-Submarine Warfare Continuous Trail Unmanned Vessel – is currently in the sea trial phase. Designed to detect and automatically track submerged vessels, this 130-foot unmanned vessel can operate autonomously for 70 days, and carry diverse non-conventional sensor technologies.[599] These drone programs each erode the opacity of the ocean in their own way, and are intended to operate in a network with aircraft or submarines that may pursue actual engagement with enemy vessels. The overall goal is to connect multiple types of mobile, deployable, and *in situ* sensors into a network that autonomously and automatically reacts to maintain the precise location of a potential target.

One persistent challenge for hypothetical networks of swarming AUVs is the need to communicate between vehicles. Individual mobility and group coordination requires wireless communication. Underwater acoustic communications are low bandwidth and must occur at close range, such that coverage of a wide area requires a large number of

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[596] Jeffrey Krolik, "Upward Falling Payloads (UFP)," Program Information (Defense Advanced Research Projects Agency, December 9, 2013).
[597] Blagden, "What DARPA's Naval Drone Could Mean for the Balance of Power"; Geoff Dyer, "US to Sail Submarine Drones in South China Sea," *Financial Times*, April 17, 2016.
[598] Patrick Tucker, "Navy Plans To Deploy A Submarine Drone Squadron By 2020," *Defense One*, October 27, 2015.
[599] Richard R. Burgess, "Follow That Sub," *Seapower*, July 2013; A. Prasad, "Darpa Builds Drone to Hunt down Submarines," *International Business Times*, February 16, 2016.

AUVs with sophisticated on board 'reasoning.'[600] Surface radio communications have a longer range, but require making the AUV vulnerable by surfacing and raising antennas.[601] While networked underwater communication is the subject of on-going research, one simple solution would be the deployment of a large number of densely packed AUVs. Another option is networking with other platforms, such as 'gateway buoys,' whose primary purpose is the facilitation of networked communication. These strategies carry their own costs and vulnerabilities.

Improvements in Acoustic Detection

Despite some technological advances, the balance between acoustic methods of hiding and seeking remains about where it was at the end of the Cold War. Acoustic systems locating submarines have been both downgraded and enhanced. Several of the SOSUS networks operated by the US military have been shut down or repurposed for non-military ends.[602] A small set of regional sonar arrays, however, has been augmented and updated in three ways: by adding new kinds of mobile sensors, improving communication between sensors, and networking with the hydrophone arrays of allies.[603] The development and deployment of multistatic sonar entails technical performance

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600 Hughes et al., "Collaborative Multistatic ASW Using AUVS: Demonstrating Necessary Technologies."
601 Button et al., *A Survey of Missions for Unmanned Undersea Vehicles*, 103.
602 William J. Broad, "Scientists Fight Navy Plan to Shut Far-Flung Undersea Spy System," *The New York Times*, June 12, 1994.; Edward C. Whitman, "First-Generation Installations and Initial Operational Experience," *Undersea Warfare*, Winter 2005; Jeremy Page, "Underwater Drones Join Microphones to Listen for Chinese Nuclear Submarines," *The Wall Street Journal*, October 24, 2014.
603 Jeremy Page, "Underwater Drones Join Microphones to Listen for Chinese Nuclear Submarines," *The Wall Street Journal*, October 24, 2014; Jeremy Page, "As China Deploys Nuclear Submarines, U.S. P-8 Poseidon Jets Snoop on Them," *The Wall Street Journal*, October 24, 2014; Barbara Honegger, "Naval Postgraduate School Pioneers 'Seaweb' Undersea Sensor Networks," *Naval Postgraduate School Public Affairs*, August 12, 2010; "Captain Nemo Goes Online," *The Economist*, March 9, 2013; Dale Green, "Autonomous 4D Underwater Environmental Sampling.," *Sea Technology* 46, no. 10 (October 2005): 51–53.

improvements, and facilitates operation in a larger network.[604] The Integrated Undersea Surveillance System includes SOSUS arrays, the Surveillance Towed Array Sensor System, and other fixed and mobile acoustic systems. The operational concept envisions a global network of submarine 'seekers,' including deployable sensors that connect readily with other platforms and the hydrophones of allies, "like an underwater internet."[605] This vision has only been partially realized in the 'sector location' tactic that coordinates P-8 Poseidon surveillance planes, satellites, passive hydrophones, and surface ships towing arrays. One basic obstacle is the slow communication speeds through water, which were described by one authority as "roughly where the Internet was 30 years ago."[606] The acoustic environment of the East Asian littoral seas, where the concept has primarily been tested, is especially challenging for passive sonar.

The challenging littoral environment, combined with improvements in submarine quieting in the late Cold War, prompted western navies to increase their investment in active sonar technology.[607] Mid-frequency active sonar was already a standard tactical tool for surface ships, but lower frequencies promised superior detection ranges. Low-frequency active (LFA) sonar was developed in the late 1980s and deployed in the 1990s on towed arrays, which could be placed below the warm surface layer.[608] Variable depth LFA sonar quickly became the 'sensor of choice' among western navies, although it still operates among a wider network of mobile and fixed passive arrays. Active sonar faces

[604] Robert Been et al., "Multistatic Sonar: A Road to a Maritime Network Enabled Capability" (Undersea Defence Technology Europe, Naples, Italy: NATO Undersea Research Centre., 2007), 9.
[605] Owen R. Jr. Cote, How will new Submarine Sensors and Payloads Influence Naval Warfare in the 21st Century?, June 4, 2012; "Captain Nemo Goes Online."
[606] Page, "Underwater Drones Join Microphones to Listen for Chinese Nuclear Submarines."
[607] John Pike, "Low-Frequency Active (LFA)," Intelligence Resource Program (Federation of American Scientists, June 21, 1997).
[608] Angela D'Amico and Richard Pittenger, "A Brief History of Active Sonar," *Aquatic Mammals* 35, no. 4 (December 1, 2009): 430.

many of the same challenges as passive sonar in the littoral environment, including high ambient noise, reverberation, and coastal mixing that disrupts temperature and density-based ocean layers.[609] Active sonar also entails a high risk of detection and counter-attack, and is politically unpopular because of the harm it causes to charismatic mega fauna like dolphins and whales.[610] While this has led the Navy to restrict the total usage of LFA sonar, DARPA currently has a prototype program to equip an AUV with active sonar.[611]

Investments in acoustic detection also take place within fisheries management, where the technique of Ocean Acoustic Waveguide Remote Sensing represents a significant advancement in the ability to monitor fish populations. This low frequency technique, which uses the continental shelf to guide horizontal sound waves, can generate "instantaneous wide-area sensing of marine life over thousands of square kilometers."[612] The passive sonar version of waveguide remote sensing has been able to detect individual marine mammals from their vocalizations.[613] The scientists working to innovate this technique suggest that it is applicable to the detection and localization of individual submarines.[614] The active sonar version has been described as "game-changing," and

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609 Richard Scott, "Sound Effects: Low Frequency Active Sonar Comes of Age," *Jane's Navy International* 120, no. 4 (May 1, 2015): 26.
610 "Lethal Sounds" (Natural Resources Defense Council, October 6, 2008),
611 Shelby Sullivan, "Distributed Agile Submarine Hunting (DASH)" (Defense Advanced Research Projects Agency, n.d.).
612 Ankita Jain et al., "Feasibility of Ocean Acoustic Waveguide Remote Sensing (OAWRS) of Atlantic Cod with Seafloor Scattering Limitations," *Remote Sensing* 6, no. 1 (December 20, 2013): 180–208.
613 Delin Wang et al., "Vast Assembly of Vocal Marine Mammals from Diverse Species on Fish Spawning Ground," *Nature* 531, no. 7594 (March 2, 2016): 366–70.
614 Carol Naughton and Sebastian Brixey-Williams, "British Pugwash Workshop: Emerging Undersea Technologies" (National Liberal Club, Whitehall: British Pugwash, May 9, 2016), 2.

although it has not yet been deployed by militaries, its utility for ASW is rapidly being recognized.[615]

Evasive and defensive strategies remain generally effective against acoustic sensing. These include slow travel and hiding in 'shadow zones' to reduce submarine signatures.[616] Even when they are widely distributed and finely tuned, passive acoustic arrays are easily destroyed or confused by defensive technology. This is a basic acoustic advantage for opacity: "The provision of hundreds or thousands of such noisemakers could well eliminate the possibility of detecting submarines in the first place."[617] Total acoustic transparency may be unlikely, but sensor improvements still degrade the opacity of the ocean. When deployed on new platforms, and networked with other types of sensors, passive and active sonar still play an important role in the detection of SSBNs.

Innovations in Non-Acoustic Detection

At the end of the Cold War, non-acoustic detection methods were more theoretical than operational, and all were vulnerable to the same basic countermeasure: traveling deep.[618] The primary difficulties were technical: separating the signal from the noise, and accounting for environmental variability. Platform options were limited to aircraft and satellites, and each provided insufficient coverage.[619] But in the last two decades, technological advances in both sensors and platforms have created new possibilities for non-acoustic detection. The full development and integration of these sensing methods into operational platforms may entail major transparency gains.

[615] Sebastian Brixey-Williams, "Will the Atlantic Become Transparent?," vol. 2 (Pugwash conferences on science and world affairs, British Pugwash, 2016).
[616] "How Do Submarines Stay Undetected?," *The Telegraph*, October 22, 2014.
[617] Garwin, "Will Strategic Submarines Be Vulnerable?"
[618] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 17.
[619] Ibid., 23–24.

Many types of sensors have extended their ranges while reducing their size and cost, which makes placing a large quantity on small platforms both attractive and feasible.[620] When these platforms are mobile like AUVs, they can follow an SSBN as it travels into the deep. Progress has even been made against the problem of 'biofouling,' which degrades sensors and reduces their service life.[621] New types of sensors are emerging, and marine scientists have a strong interest in the development and deployment of non-acoustic sensors. The signatures that can be observed by non-acoustic detection methods depend on the properties of the submarine itself, and its interactions with the ocean environment. These can include electromagnetic effects, biological disturbances, internal and surface waves, temperature change, optical reflectivity or absorption, and chemical or radioactive tracers.[622] A survey of the most promising non-acoustic detection methods suggests that their contribution to ocean transparency may be significant. Four types of non-acoustic detection will be considered.

LIDAR measures distance using the reflections of lasers, and the method has been successfully used in seafloor mapping and mine detection.[623] Although LIDAR has been the subject of optimism regarding submarine detection, it is unlikely to overcome the problem of 'backscatter' from the clouds and sea surface, which reduces the signal strength.[624] This method of non-acoustic detection is ultimately thwarted by ocean geophysics; "there is no possibility of strategically significant blue-green laser ASW because even the optimum laser color does not penetrate (in a round-trip) to the

[620] Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare," 9.
[621] Javeed Shaikh Mohammed, "Micro- and Nanotechnologies in Plankton Research," *Progress in Oceanography* 134 (May 2015): 451–73.
[622] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 183.
[623] Kopp, "Evolving ASW Sensor Technology," 29.
[624] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 21.

comfortable operating depth of existing submarines."[625] LIDAR might be useful for short-range localization of shallow submarines, but it is ineffective for wide-area surveillance.[626] These barriers are unlikely to be overcome by technology.

Another non-acoustic signature that could theoretically be detected is the effect of submarine transit on marine microorganisms, especially those with bioluminescent reactions.[627] Because oceanography had an early and persistent focus on geophysical systems – encouraged by the Office of Naval Research – detection and modeling of chemical and biological systems is especially immature.[628] But marine scientists increasingly understand these conceptually distinct systems as a single integrated biogeochemical system, such that it is theoretically possible to measure biological effects as proxies for the physical effects of submarines. Some biological effects are being actively monitored; ocean color remote sensing from satellites is used to derive productivity baselines from algal blooms.[629] And the relevance of micro- and nanotechnology for plankton research is increasingly recognized.[630] But these biological sensor systems remain fundamentally immature, and this detection method is easily evaded by diving deep, where less prevalent bioluminescence is too deep to shine up to the surface anyway.[631]

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[625] Garwin, "Will Strategic Submarines Be Vulnerable?," 61.
[626] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 22.; Naughton and Brixey-Williams, "British Pugwash Workshop: Emerging Undersea Technologies," 3.
[627] G.G. Wren and D. May, "Detection of Submerged Vessels Using Remote Sensing Techniques," *Australian Defence Force Journal*, no. 127 (1997): 11–13.
[628] Hamblin, *Oceanographers and the Cold War*; Glickson et al., *Oceanography in 2025*.
[629] David Blondeau-Patissier et al., "A Review of Ocean Color Remote Sensing Methods and Statistical Techniques for the Detection, Mapping and Analysis of Phytoplankton Blooms in Coastal and Open Oceans," *Progress in Oceanography* 123 (April 2014): 123–44.
[630] Mohammed, "Micro- and Nanotechnologies in Plankton Research."
[631] Stefanick, *Strategic Antisubmarine Warfare and Naval Strategy*, 18.

A more promising technique, Magnetic Anomaly Detection (MAD) seeks out disturbances in the Earth's magnetic field caused by the transit of a submarine. MAD is a mature technology that is deployed by patrol aircraft, but it has a limited range that makes it incapable of wide area surveillance.[632] Plans to deploy MAD on aerial drones launched from patrol aircraft (specifically the P-8 Poseidon) could expand its range, but a more significant breakthrough exists on the horizon. The application of 'Superconducting Quantum Interference Devices' (SQUID) to MAD promises major advances in sensitivity and range. SQUID magnetometers have been used in oil exploration, mapping tectonic faults, and biomedical imaging.[633] The emergence of micro-cryogenic cooler technology enables the application of SQUID to military surveillance.[634] Increasingly detailed maps and models of the Earth's magnetic field complement the increased sensitivity of SQUID sensors, and decrease false alarm rates. "The full potential of MAD techniques remains to be exploited in operational systems," but the availability of drone platforms and the improvement in sensor range makes this detection technology promising.[635]

Another promising technique looks for disturbances in the circulation of ocean water. The passage of a submarine creates internal waves in the vertical layers of the ocean, and two types of surface waves that trail behind it. Earth system scientists regularly use satellite-based remote sensing to measure properties of the sea surface such as its height, temperature, salinity, color, and surface currents. Yet surface waves remain difficult to detect because of "the enormous variability of ocean surface conditions."[636]

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[632] Wren and May, "Detection of Submerged Vessels Using Remote Sensing Techniques," 10.
[633] Jennifer Ouellette, "SQUID Sensors Penetrate New Markets," *Industrial Physicist* 4, no. 2 (June 1998): 21.
[634] Hambling, "The Inescapable Net: Unmanned Systems in Anti-Submarine Warfare," 3–4.
[635] Kopp, "Evolving ASW Sensor Technology," 28.
[636] Ibid.

The resolution and coverage of sea-surface measurements is insufficient to detect these patterns with consistency and precision. Internal waves below the surface may actually be more promising for detection. Oceanographers of all types could benefit from more informed maps and models of ocean layering and turnover, and such knowledge is also critical for understanding the challenge of climate change.[637] This sought-after knowledge provides important information about environmental variation that could be useful for separating a signal from noise. Internal waves caused by the transit of a submarine propagate a long distance along density layers, so the signal is not miniscule. Satellite-based Synthetic Aperture Radar is capable of identifying the main features of internal waves from the modulations they cause at the sea surface.[638] Advances in scientific knowledge about ocean layering will improve the precision of this detection technique.

Technological developments in the last few decades have overcome major technical hurdles to detection that ensured the persistence of opacity throughout the Cold War. AUVs solve two problems for surveillance: they make it impossible to hide in the deep, and they reduce noise by getting sensors closer to the signal. Acoustic sensing is still limited by the problem of noise, but augmented through the deployment of multiple networked platforms. At least two non-acoustic signatures – magnetic anomalies and internal waves – are increasingly detectable. The “robotization of the oceans” is beginning, and the number and variety of stationary and mobile sensors is projected to increase drastically in pursuit of military and non-military objectives.[639] Even if sensors

[637] Victor Klemas and Xiao-Hai Yan, “Subsurface and Deeper Ocean Remote Sensing from Satellites: An Overview and New Results,” *Progress in Oceanography* 122 (March 2014): 2.
[638] Ibid., 6.
[639] Matt Simon, “Brave Robots Are Roaming the Oceans for Science,” *Wired*, April 13, 2015.

themselves are limited, greater transparency may be achieved through sheer technological presence. The multiple drivers of these technologies, and the investment of militaries in both hiding and seeking, mean that no single actor is in control of this situation.

Conclusion

If ocean transparency made nuclear strategic submarines more detectable, locatable, and targetable, the military and political implications would be significant. Yet the topic of SSBN vulnerability is "virtually taboo" in the US Navy's public documents.[640] A culture of complacency has set in regarding the role and missions of SSBNs, such that submariners are poorly equipped to adjust to potentially novel operational realities.[641] And other countries are walking the same path: the planned development of SSBNs by India and Pakistan is driven by a judgment about their superior and durable survivability.[642] This chapter challenges the assumption that extrapolations from the past can serve as reliable guides for the future, especially as regards the foundation of the world nuclear order. Specifically, the security of second-strike capabilities, and therefore the assurance of mutual destruction, rests on fluid material foundations. Whether the potential obsolescence of 'hiding' technologies occurs as a slow erosion of usefulness, or an avalanche of illumination, could have serious implications for nuclear strategic stability.

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[640] Moltz, "Submarine and Autonomous Vessel Proliferation: Implications for Future Strategic Stability at Sea," 2.

[641] Brian McGuirk, "Rekindling the Killer Instinct," *U.S. Naval Institute Proceedings* 138, no. 6 (June 2012): 40–45; Coughlin, "Reclaiming Antisubmarine Dominance."

[642] Iskander Rehman, "Drowning Stability: The Perils of Naval Nuclearization and Brinkmanship in the Indian Ocean," *Naval War College Review* 65, no. 4 (Autumn 2012): 64–83.

The possibility of, and reactions to, ocean transparency present a challenge for the prevailing arms control regime. The force structures created and shaped by existing arms control treaties assume the superior survivability of SSBNs as the foundation of nuclear deterrence. If transparency were to arrive as a "technological surprise," this feature of the regime sets the stage for instability.[643] Without invulnerability, nuclear states may pursue a 'safety in numbers' approach to achieving a secure second strike, which would require a substantial buildup in weaponry. The pursuit of 'launch on warning' postures conflicts with the arms control agenda of "lengthening the fuse."[644] And if 'mutually assured destruction' were abandoned wholesale, the possible return to a 'war strategism' approach that sees nuclear weapons as usable would be especially detrimental to the arms control agenda. An arms control regime that accounts for the possible erosion of transparency might replicate the Treaty on Open Skies, which regulates the frequency and resolution of aircraft surveillance.[645] This strategy would entail rebuilding opacity by treaty where it may be undermined by technology.

It is unlikely that the ocean will become transparent everywhere, all at once. While predicting exactly how and where transparency will be achieved is impossible, this analysis suggests where to look in order to see transparency coming. Broad and precise ocean sensing requires advanced technology, which is restricted to technically proficient actors with substantial funds. But new motivations and open-access oceanography imply that such innovations may not be limited to the US military. The variegated terrains of the vast ocean create different sets of opportunities and challenges for hiding and seeking in

[643] Elbridge A Colby et al., *Strategic Stability: Contending Interpretations*, 2013.
[644] Harold A. Feiveson and Bruce G. Blair, eds., *The Nuclear Turning Point: A Blueprint for Deep Cuts and de-Alerting of Nuclear Weapons* (Washington, DC: Brookings Institution Press, 1999).
[645] Sean P. Larkin, "The Age of Transparency: International Relations Without Secrets," *Foreign Affairs*, April 18, 2016.

the sea, so that transparency is likely to be a regional phenomenon before it is a global one. Who is investing, and what regions matter, is substantially a function of contemporary international politics. The ocean operational environment has historically been a good place to secure a second strike capability, but increased understanding and advancing technology may soon undermine the opacity that strategic submarines have hidden behind since the 1960s.

Global Ocean: The Modern Ocean Governance Regime

After World War II, significant advances in science and technology related to the ocean created a new set of opportunities and challenges for ocean governance.[646] Remote fisheries and fossil fuel resources were increasingly accessible, but the problems of depletion and marine pollution seemed to be worsening. Many countries began making unilateral claims over the continental shelves and water columns abutting their coastlines. Yet the idea of a single global ocean was also taking shape, and taking hold among the international community.[647] Governments saw an increasing need to come to agreement about how ocean space and ocean resources should be shared and managed. A series of three United Nations Conferences on the Law of the Sea (1956-58, 1960, and 1973-82) attempted to generate agreement about principles, rules, and norms for the ocean, and to construct a new formal regime for ocean governance. The final conference succeeded in creating a 'Constitution for the Oceans,' which most of the international community has now ratified, and which has come to be understood as having the status of customary international law.[648]

A massive diplomatic effort went into the negotiation of the U.N. Convention on the Law of the Sea, which entailed nine years of conferences, multiple and shifting coalitions, bargaining, concessions, the exchange and reconciliation of drafts, and dealing with the full suite of non-military ocean uses. The 1970s were a high water mark in international regime building, especially regarding the collective management of

[646] John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 44.
[647] Alan Villiers, *Oceans of the World: Man's Conquest of the Sea* (Museum Press, 1963). 13
[648] Tommy T.B. Koh, "A Constitution for the Oceans," n.d.

international spaces.[649] The Cold War superpowers had strategic and economic interests in building predictable rules and norms for global spaces, and could gain prestige by taking on leadership roles in international negotiations. But while the prevailing gusto for regime building may explain part of the motivation behind UNCLOS, it does not explain the specific content of the regime, and cannot fully explain its many failures. This chapter considers how the content and effectiveness of the UNCLOS-centered ocean governance regime is influenced by scientific knowledge of, and technological capability in, the global ocean.

The basic argument of this chapter is that the modern ocean governance regime was bound to fail. The salience of technological practices, combined with uncertainty about collective interests and the structure of collective problems, produced barriers to effectiveness that are 'baked in' to the ocean governance regime. The central focus of critique will be on the U.N. Convention on the Law of the Sea (UNCLOS), because of its breadth of topics and membership, and the novel political geography it created. The first section reviews the changes in human understanding and use of the global ocean that occurred in the decades leading up to the negotiation of UNCLOS. The second section describes the main features of UNCLOS, and how the formation of the regime was influenced by geographic, ecological, and technological factors. The third section considers the question of effectiveness, focusing especially on whaling, fishing, and marine pollution. Many of the issues with UNCLOS will be explored in the next chapter,

[649] Other international institutions negotiated during this period include: Seabed Arms Control Treaty (1971), the Convention on International Liability for Damage Caused by Space Objects (1972), the Convention on the Registration of Objects Launched into Outer Space (1976), the Environmental Modification Convention (1978), and the Convention on Long-Range Transboundary Air Pollution (1979)

which covers the period in the late 20th and early 21st century, during which UNCLOS was augmented and reformed.

The Globalized Ocean

Although maritime circumnavigation first occurred in the early modern period, it was not until the 20th century that most ocean activities took on a truly global scale, and the ocean began to be systematically contemplated and understood in its entirety. This expanded scale of experience and exploitation set a new stage for international politics, and served as the foundation for the formation of a broader and more formalized ocean governance regime. This section describes the contours and patterns of the modern global ocean.

Technological Exploitation

The period between World War II and the opening of the third UNCLOS negotiations encompassed a marked industrialization of ocean uses.[650] Fishing became even more mechanized through the use of new technologies, including fish-finding sonar, on-board refrigeration, lighter and stronger nets, and trawling.[651] In the 1950s, pelagic fishing became the majority of the total catch, driven in part by state-sponsored Japanese and Soviet long-distance fishers. Latin American fishing also grew dramatically.[652] By the 1960s, fisheries were by far the most valuable economic resource in the ocean, and by the 1970s half of all fish caught were traded internationally.[653]

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[650] Hance D Smith, "The Industrialisation of the World Ocean," *Ocean & Coastal Management* 43, no. 1 (January 2000): 11–28.
[651] Elizabeth R DeSombre and J. Samuel Barkin, *Fish* (Oxford: Wiley, 2013); Carmel Finley, *All the Fish in the Sea: Maximum Sustainable Yield and the Failure of Fisheries Management* (Chicago; London: University of Chicago Press, 2011).
[652] DeSombre and Barkin, *Fish*, 30.
[653] Ann L Hollick, *U.S. Foreign Policy and the Law of the Sea* (Princeton, N.J.: Princeton University Press, 1981), 176.; Smith, "The Industrialisation of the World Ocean," 21.

Long-distance fishers preferred a norm of open access, while coastal states preferred ownership and control of local resources. For example, long-distance tuna fishers from the United States wanted access to the waters off South America. In contrast, US salmon fishers off the coast of Alaska preferred the prohibition of foreign fishing. Despite, or perhaps because, of these conflicting interests, no strong regime was established or enforced in the immediate post-war years. Many fish populations collapsed in the late 1950s and early 1960s, most notably Bluefin tuna.[654] The possibility of over-fishing as a regional, or even global problem first arose during this period.

Global whaling collapsed earlier and harder than global fisheries. In the mid-18th century, new on-board processing technology enabled whalers to stay at sea for months or years at a time. During this period, whale oil was in demand for lighting, lubricants, soaps, perfumes, and margarine, and pliant whale baleen was used for corsets, umbrellas, and industrial brushes.[655] The Pacific sperm whale population collapsed in the 1850s, and the Atlantic Great Northern whale population collapsed in the 1880s.[656] Mechanization greatly improved whalers' ability to hunt, kill, and process whales. In 1946, the International Whaling Commission (IWC) was created "to manage hunting for the sake of the industry, not that of the whales."[657] But it failed to stem exploitation enough to allow populations to rebound, and as a whole, global whaling peaked in the 1950s and

[654] Darlene Trew Crist, Gail Scowcroft, and James M. Harding, *World Ocean Census: A Global Survey of Marine Life* (Richmond Hill, Ont. ; Buffalo, New York: Firefly Books, 2009), 72.
[655] Lincoln P. Paine, *The Sea and Civilization: A Maritime History of the World*, First Edition (New York: Knopf, 2013), 541.
[656] H.D. Smith, "The Development and Management of the World Ocean," *Ocean & Coastal Management* 24 (1994): 8.
[657] Robert C. Rocha, Jr., Phillip J. Clapham, and Yulia Ivashchenko, "Emptying the Oceans: A Summary of Industrial Whaling Catches in the 20th Century," *Marine Fisheries Review* 76, no. 4 (March 3, 2015): 47.

1960s.[658] Many populations were totally extirpated, and some species were reduced to tiny fractions of their pre-whaling numbers. This failure of the IWC to stem the tide of over-exploitation will be considered in the third section.

In addition to the intensification of existing uses of the ocean, new technologies in the post-war era generated new types of practices in the ocean. Naval warfare had been progressively revolutionized through the introduction of steam power, torpedoes, larger and faster ships, and submarines. After World War II, military ships, coast guards, and submarines plied the global ocean in large numbers. The advent of nuclear weaponry introduced a new sink source, in that nuclear waste began to be dumped regularly into the ocean.[659] Offshore oil drilling expanded dramatically in the 1960s, due to advances in the technology of stationary drilling structures, which were able to handle greater depths and more severe weather conditions.[660] Trans-national shipping was revolutionized in the late 1960s and 1970s with the advent of container shipping, intensifying global economic interdependence.[661] The 1960s were full of optimism, and "observers anticipated the inevitable and speedy inauguration of new modes of travel, recreation, work and life undersea."[662] Most users and beneficiaries of the ocean environment were interested in more.

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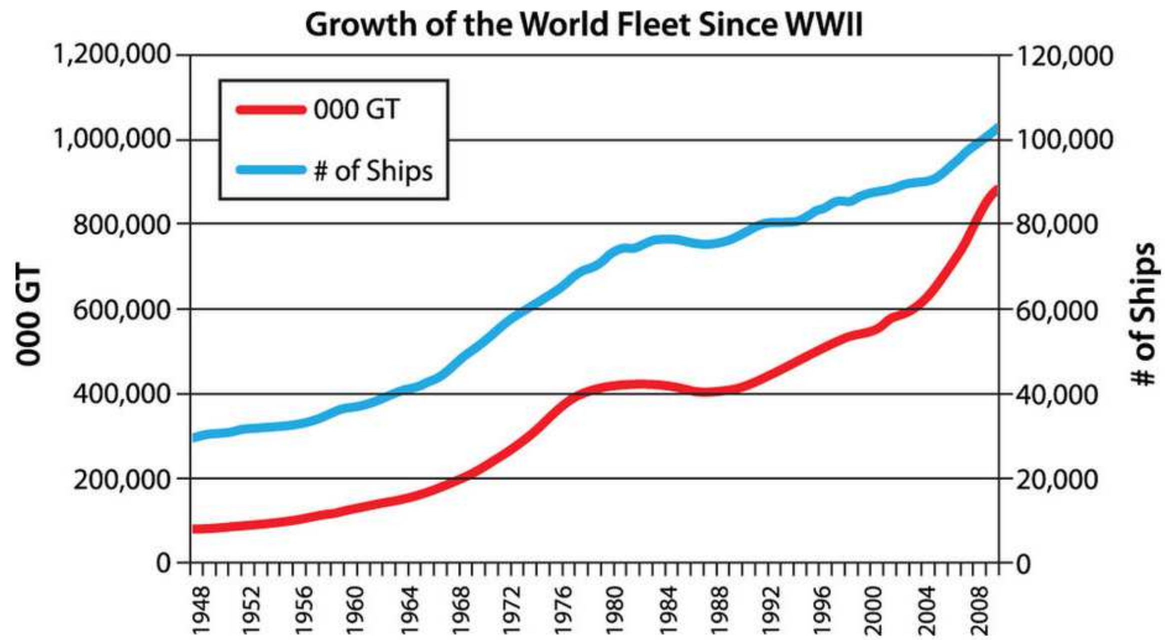
[658] Smith, "The Industrialisation of the World Ocean," 20.;Rocha, Jr., Clapham, and Ivashchenko, "Emptying the Oceans."

[659] Jacob Darwin Hamblin, *Poison in the Well: Radioactive Waste in the Oceans at the Dawn of the Nuclear Age* (New Brunswick, N.J.: Rutgers University Press, 2008).

[660] Helen M. Rozwadowski, "Engineering, Imagination, and Industry: Scripps Island and Dreams for Ocean Science in the 1960s," in *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment* (Sagamore Beach, Mass: Science History Publications/USA, 2004), 315–54; Smith, "The Industrialisation of the World Ocean," 18.

[661] Smith, "The Industrialisation of the World Ocean"; Marc Levinson, *The Box How the Shipping Container Made the World Smaller and the World Economy Bigger* (Princeton, N.J.; Woodstock: Princeton University Press, 2008),.

[662] Rozwadowski, "Engineering, Imagination, and Industry: Scripps Island and Dreams for Ocean Science in the 1960s," 316.



The growth of the world fleet[23] for the time period of interest is shown as an increase in the gross tonnage (in red) and the number of ships (in blue).

Oceanography

Oceanography became professionalized in the early 20th century, including the creation of major national research institutions, inter-governmental organizations, and the first comprehensive textbook.[663] Two US institutions quickly became known for 'cutting edge' oceanography: the Scripps Institution of Oceanography in San Diego, and the Woods Hole Oceanographic Institution in Massachusetts. After World War II, the center of oceanographic activity "shifted decisively" to the United States, especially due to the ample funding provided by the Office of Naval Research, established in 1946.[664] Due in large part to this military patronage, the primary research focus of oceanography remained geophysical, including data-collection and theory building surrounding ocean

[663] H.U. Sverdrup, Martin W. Johnson, and Richard H. Fleming, *The Oceans. Their Physics, Chemistry, General Biology* (Prentice Hall, 1942).
[664] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005), 11.

circulation, seafloor topography, and sound propagation.[665] The oceanography-military connection was mutually beneficial in several ways. To take just one example, nuclear testing created an opportunity for use of radioactive tracers to study ocean mixing and circulation.[666]

International cooperation in oceanography occurred frequently during the middle decades of the Cold War. After World War II, the US Department of State used marine sciences as a foreign policy tool to forge positive relations with Japan, and as a humanitarian means to assist developing countries in establishing modern fisheries. The first Pacific Science Congress after the war was held in Manila in 1953, with the purpose of encouraging cooperation in scientific research among Pacific states.[667] The US Navy sponsored cooperative data collection in the Pacific during the 1950s, bringing together researchers from the United States, Canada, and Japan.[668] The most significant international scientific endeavor during this period was the 1957 International Geophysical Year (IGY) – a massive, collaborative global data-gathering event that "aimed to extend synoptic data collection over the entire Earth."[669]

The IGY was a remarkable endeavor, "the largest set of coordinated experiments and field expeditions to be undertaken during the cold war."[670] It involved tens of thousands of scientists from 67 countries, collecting data in a planned and coordinated

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[665] Georg Wüst, "The Major Deep-Sea Expeditions and Research Vessels 1873–1960," *Progress in Oceanography* 2 (January 1964): 1–52; Hamblin, *Oceanographers and the Cold War*.
[666] Ronald Rainger, "'A Wonderful Oceanographic Tool': The Atomic Bomb, Radioactivity and the Development of American Oceanography," in *The Machine in Neptune's Garden: Historical Perspectives on Technology and the Marine Environment*, ed. Helen M. Rozwadowski and David K. Van Keuren (Sagamore Beach, Mass: Science History Publications/USA, 2004), 93–94.
[667] Robert B. Hall, "EIGHTH PACIFIC SCIENCE CONGRESS," *The Professional Geographer* 6, no. 2 (March 1954): 33–33.
[668] Hamblin, *Oceanographers and the Cold War*, 28.
[669] Ibid., 30.
[670] Fae L. Korsmo, "The Genesis of the International Geophysical Year," *Physics Today* 60, no. 7 (July 2007): 38–43.

way in order to provide evidence for testing nascent theories about planetary domains.[671] Although IGY planning initially focused on the poles, the atmosphere, and outer space, oceanographers saw an opportunity for "global studies involving simultaneous multiple observations," and therefore took the lead in creating a research agenda.[672] The IGY program for oceanography investigated many different problems and questions, including deep ocean circulation and the nature of variations in biotic productivity. It was hoped that new knowledge about ocean properties would "make it possible to harvest the seas methodically, instead of haphazardly."[673] Although the IGY produced important discoveries about ocean circulation and deep-sea life, it failed to live up these high expectations. The Soviet-led data collection program was "uninspired" and not keyed to specific problems, and even the US projects are described as only "observational expeditions" or "descriptive exploration."[674] Indeed, the most important legacy of the IGY may be renewed scientific competition between the United States and Soviet Union.[675]

The IGY was the major exception to a more general trend of scientific secrecy during the Cold War. The Central Intelligence Agency kept close tabs on IGY activities, because domain-specific knowledge could provide important military advantages.[676] After the IGY, oceanographers became divided politically and scientifically, such that

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[671] Paul Lagassé and Columbia University, eds., "International Geophysical Year," in *Columbia Electronic Encyclopedia*, 6th ed (New York: Columbia University Press, 2017).
[672] Hamblin, *Poison in the Well*, 126.
[673] Walter Sullivan, *Assault on the Unknown: The International Geophysical Year* (New York: McGraw-Hill, 1961), 348.
[674] Hamblin, *Oceanographers and the Cold War*, 71, 76.
[675] Ibid., 96.
[676] Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford: Oxford Univ. Press, 2013), 92.

isolated pockets of scientific knowledge emerged.[677] Scientists may have contributed to this trend by vacillating between two justifications for their research: benefit for humanity as a whole, and support of specific national interests. When appealing to government and military sources for funding, oceanographers often emphasized the national security relevance of their research. The problem of restrictions on science worsened in the late 1960s, when many states concerned about the protection of coastal resources began restricting access in areas "most vital to marine research."[678] Coastal developing states argued "even where research was not of a commercial or military nature, it would benefit the developed researching state more" and therefore should be controlled in order to avoid worsening the growing gap between developed and developing countries.[679] The rights of marine scientific researchers would become an important topic during the UNCLOS negotiations.

Despite significant advancement in physical oceanography and seafloor geology during this period, much about the ocean remained unknown. The development of a comprehensive theory of ocean circulation was a major advancement, but rife with errors due to its assumption of a flat seafloor and inability to account for vertical mixing.[680] Marine scientists believed the deep ocean was stagnant until IGY research produced evidence of deep ocean circulation. Debates about the theory of plate tectonics could not be resolved without data collection from the seafloor, which began in earnest in the 1960s.[681] When UNCLOS III began, negotiators lacked a synoptic map of the seabed.

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[677] Hamblin, *Oceanographers and the Cold War*, 52.
[678] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 180.
[679] Ibid., 277.
[680] Eric L Mills, *The Fluid Envelope of Our Planet: How the Study of Ocean Currents Became a Science*, 2011.
[681] Hamblin, *Oceanographers and the Cold War*.

They finally got one in 1977 – Marie Tharp's World Ocean Floor Panorama, which included the mid-Atlantic ridge and rift valley for the first time. Despite major gains in data and research support, physical oceanography was just at the beginning of major theory development about the dominant scales of ocean circulation, the causes of upwelling and nutrient flow, and molecular exchange with the atmosphere.

Rapid growth in knowledge of ocean ecology occurred during this period. Despite obvious depletion in some fisheries, both scientists and the general public still assumed that the ocean was abundant with life. The 1950s and 1960s were a period of extreme optimism about the bounty of the global ocean, which was perceived as an expansive sink, a "great neutralizer, with virtually unlimited ability to absorb noxious substances."[682] Both academic and popular books heralded the abundance of its resources in titles like *The Inexhaustible Sea* (1954), *The Bountiful Sea* (1964), and *Riches of the Sea* (1968). Problems associated with pollution and over-exploitation did not concern most researchers. The ocean seemed even more full of life than previously thought. In the 1960s, the use of deep-sea submersibles established the presence of deep ocean ecosystems, and in the 1970s a whole new kingdom of life (Archaea) was found.[683] Hydrothermal vents and their unique ecosystems were discovered in 1977.

These discoveries belied the fact that knowledge of the most exploited ecosystems was extremely limited. Direct sampling of oceanic organisms faced major obstacles; tagging of animals was rudimentary and unable to collect detailed data. Lack of baseline data about many marine processes prevented detection of trends and disruptions. Yet the effects of over-exploitation were becoming hard to deny, and emerging concern about

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[682] Hamblin, *Arming Mother Nature*, 99.
[683] Jon Bowermaster, ed., *Oceans: The Threats to Our Seas and What You Can Do to Turn the Tide: A Participant Media Guide*, 1st ed (New York: PublicAffairs, 2010).

over-fishing prompted the development of mathematical models of population growth. In the context of these concerns, the idea of 'rational fishing' emerged. Fish population models, intended to identify the optimal rate of harvest, were based on the philosophy of German scientific forestry, and rooted in a metaphor of terrestrial agriculture.[684] American fisheries scientists were especially confident about their ability to rationally manage a fishery, and their concept of a 'maximum sustainable yield' was embedded in fisheries policy by 1958. In the following decade, spending on fisheries research represented less than one-tenth of total funding for the Federal Marine Sciences Program in the United States.[685]

These perceptions of a resource-rich ocean subject to rational exploitation began to unravel in the 1960s, with books like *The Frail Ocean* (1967) spreading awareness of actual and potential ecological degradations and resource conflicts.[686] *The Frail Ocean* begins by acknowledging the change in perception, warning readers "it may be difficult to accept the fact that our progress can mean death to the ocean."[687] This new understanding that the "technological penetration of the ocean is…potentially disastrous" was bolstered by the rapid growth of oceanographic work.[688]A boom in oceanography continued through the 1970s, a decade during which the number of oceanographers doubled every four years.[689] Marine science increasingly incorporated the 'framework science' of ecology, broadening the factors deemed relevant for fisheries.[690] But scientific

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684 Finley, *All the Fish in the Sea*, 68, 165.
685 Hollick, *U.S. Foreign Policy and the Law of the Sea*, 176.
686 Rozwadowski, "Engineering, Imagination, and Industry: Scripps Island and Dreams for Ocean Science in the 1960s," 344.
687 Wesley Marx, *The Frail Ocean* (American Book - Stratford Press, Inc., 1967), 1.
688 Ibid., 6.
689 Brenda Horsfield, *The Great Ocean Business* (London: Hodder and Stoughton, 1972), 1.
690 Peter M. Haas, *Saving the Mediterranean: The Politics of International Environmental Cooperation*, The Political Economy of International Change (New York: Columbia University Press, 1990).

consensus about diffuse threats to ocean ecology was undeveloped and/or invisible, from the perspective of international negotiators at UNCLOS III. More visible and salient were vested interests in continued and expanded resource exploitation.

Ocean Governance Regime

The ocean governance regime is composed of several distinct institutions, all of which were created after World War II. Two sector specific organizations are the International Whaling Commission (1946) and the International Maritime Organization (1959), which deals with shipping regulations. Two treaties cover maritime pollution, OILPOL (1954) and MARPOL (1973/78). But the focal point of the global ocean governance regime is the UNCLOS treaty, which came out of the third UNCLOS conference. The first two conferences in 1958 and 1960 had failed to resolve major disagreements about the territorial sea and other jurisdiction zones. The third conference took place from 1973 until 1982, when representatives of over 150 states convened eleven times to discuss the terms of the Law of the Sea Treaty (called 'UNCLOS'). In the words of the president of the UNCLOS III conference, Tommy Koh of Singapore, the fundamental objective of these negotiations was the creation of a "comprehensive constitution for the oceans which will stand the test of time."[691] The basic purpose of the 'ocean constitution' was to ensure sustainable and equitable use of ocean resources. UNCLOS was intended to serve as an umbrella for existing governance institutions, and for any treaties to follow. This section will first consider the creation of the watershed UNCLOS agreement, which serves as a framework for the rest.

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[691] Koh, "A Constitution for the Oceans."

United Nations Convention on the Law of the Sea

The catalyst for regime building was a wave of unilateral declarations of ownership over ocean resources, triggered by two 'proclamations' made by the Truman administration in 1945. The Truman Proclamations asserted jurisdiction over natural resources on and above the entire contiguous continental shelf. In the next five years, ten Latin American governments made similar, but diverse, declarations. The need for international justification led Chile, Peru, and Ecuador to coordinate the content and defense of their claims, which expanded to include full sovereignty 200 miles from their coastlines. The choice of 200 miles was made for different reasons, which were "obscured by the development of sophisticated legal rationales to buttress a claim which, at the outset, served a very limited range of economic interests and found little support in the then prevailing international law of the sea."[692] UNCLOS I and II had limited agendas, and extremely limited success in adjudicating between these competing claims. Developing states in Africa latched onto the concept of seaward extension of jurisdiction in the 1970s, and in 1972 Kenya presented a working paper entitled "Exclusive Economic Zone Concept" to an Asian-African Legislative Consultative Committee.[693] It was this group – developing coastal states with a strong interest in keeping developed maritime states away from their resources – that brought the idea to UNCLOS III. [694] The territorial and jurisdiction zones created by UNCLOS are a central feature of its legacy.

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[692] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 75.
[693] Oude Elferink, Alex. G. *Stability And Change in the Law of the Sea: The Role of the Los Convention*. Leiden, The Netherlands: Martinus Nijhoff Publishers, 2005. 33. Print.
[694] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 877–92.

When UNCLOS III began in 1973, "the law of the sea was in a state of disorder bordering on chaos."[695] Conflicts existed over several topics, and there were three main committees to deal with substantive issues. Committee I covered seabed mining beyond national jurisdiction and Committee II handled "issues pertaining to national jurisdiction such as the economic or resource zone, the continental shelf, fishing, the territorial sea, and straits."[696] Committee III dealt with the "residual issues" of the marine environment and scientific research.[697]

The UNCLOS III negotiations were extremely complex, for three reasons. First, negotiators had a broad mandate to address "all matters relating to the law of the sea," but aimed to formulate a single treaty.[698] This "formidable negotiating task" entailed accounting for the interests of participants that were geographically, economically, and politically diverse, and dealing with all known collective action problems in the ocean.[699] Second, the length of negotiations entailed substantial turnover within state delegations, fluctuations in the power and needs of domestic interest groups, and a changing international context. The negotiations spanned a period that included the OPEC oil embargo, the end of the Vietnam War, the Soviet invasion of Afghanistan, and the independence of over twenty new sovereign states. Third, negotiations could not begin with a blank slate, but had to build on the palimpsest of hundreds of years of customary international law in addition to the relatively new suite of unilateral claims. As a result of

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[695] Alan Beesley, "The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?," *Law and Contemporary Problems* 46, no. 2 (1983): 183.
[696] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 284–85.
[697] Ibid., 242.
[698] James Harrison, *Making the Law of the Sea: A Study in the Development of International Law* (Cambridge; New York: Cambridge University Press, 2011), 37.
[699] Majumdar 2681; Hollick, *U.S. Foreign Policy and the Law of the Sea*, 286.

these three obstacles, diplomatic coalitions fluctuated between issues and over time.[700] Some general trends and patterns emerged, many of which demonstrate the significant influence of the material context.

The contours of the ocean itself are reflected in the formation of interest groups; negotiation coalitions based on geography, ecology, and technology did exist and were influential. The nature of coalitions was not primarily East vs. West or North vs. South, which would represent ideological, political, and economic divisions.[701] From the very beginning of the conference, at the agenda-setting phase, negotiation blocs formed around geographic differences and commonalities.[702] 'Geographically disadvantaged' and land-locked states had a negotiating agenda that favored revenue sharing, limited nationalization (only 12 mile territorial sea), and open access.[703] Unsurprisingly, this group "did not exert significant influence" during negotiations.[704] Archipelagic states like Fiji, Indonesia, Mauritius, Malaysia and the Philippines joined together in favor of straight baselines from which to generate jurisdictional zones. Archipelagic states sometimes sided with the "straits states," such as Cyprus, Greece, Morocco, Spain, and Yemen, but sometimes their interests conflicted.[705] Other groups included states with

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[700] Ibid., 14.
[701] Hollick, *U.S. Foreign Policy and the Law of the Sea*; Beesley, "The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?"; Sumit Majumdar, "Institutions for International Co-Operation: An Analysis of the United Nations Law of the Sea Conference and Convention," *Economic and Political Weekly* 25, no. 48/49 (December 1, 1990): 2681–85.
[702] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 240.
[703] Ibid., 383; George Galdorisi and Alan G. Kaufman, "Military Activities in the Exclusive Economic Zone: Preventing Uncertainty and Diffusing Conflict," *California Western International Law Journal* 32, no. 2 (2001): 253–303.
[704] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 383.
[705] Ibid., 294.Beesley, "The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?," 189.

semi-enclosed seas and the “margineers,” or states with broad continental shelves.[706] Coastal states were of course a significant category, but groupings were even more fine-grained; for example, Japan, Norway, and Iceland shared a strong interest in commercial whaling.

[706] Mazen Adi, “The Application of the Law of the Sea and the Convention on the Mediterranean Sea” (New York: Division for Ocean Affairs and the Law of the Sea Office of Legal Affairs, the United Nations, 2009), 27–29; Beesley, “The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?,” 189.

COMPETING GROUPS, POLITICS, AND INTERESTS AT THE THIRD UNITED NATIONS LAW OF THE SEA CONFERENCE[86]

GROUP/ COUNTRY	GEOGRAPHIC DESCRIPTION	STATES INCLUDED	GOAL/INTERESTS
Archipelagic States	Oce-anic/Island	Fiji, Indonesia, Mauritius, Philippines	Archipelagic waters by straight baseline and 200 mile economic zone
Group of 77	Africa, Asia and Latin America	120 developing nations in 1980, including Argentina, Brazil, Cuba, Burma, Syria, Thailand, Egypt, Iraq, Iran, Kenya, Malta, Saudi Arabia, and others	International Regime for seabed mining; common heritage, production limits and price control on seabed mining
Japan	N/A	N/A	Opposed to expanded claims on territorial seas and fishery zone; access to deep seabed mining
Landlocked & Geographically Disadvantaged States	All regions	48 states, including Czechoslovakia, East Germany, Hungary, Mongolia, Poland	Revenue sharing; living and non-living resource exploitation; right to participate in research; 12 mile territorial sea
Patrimonialist & Territorialist	Caribbean & Latin American	Colombia, Haiti, Jamaica, Mexico, Trinidad, Venezuela, Chile, Ecuador, Peru, Panama	200 mile zone over renewable resources and/or 200 mile territorial sea
USA	N/A	N/A	Free navigation; guaranteed free transit through straits; free access to deep seabed mining
Soviet East European Bloc	East Europe	Albania, Hungary, Czechoslovakia, Poland, Romania, Yugoslavia	Seabed mining, 200 mile EEZ; continental shelf; territorial sea; fisheries transit
Western Europe (EEC) & Group of 11	European Community, plus Scandinavians	EEC and Scandinavians, plus Australia, Austria, Canada, Ireland, New Zealand	Coastal jurisdiction over fisheries; free access to deep seabed mining.

86. This table is copied, with minor modifications, from WANG, *supra* note 66, at 448 (citing HOLLICK, *supra* note 66, at 250-56 *and* Miles, *supra* note 84, 162-66).

Figure 12 - UNCLOS negotiating coalitions, From Galdorisi, George, and Alan G. Kaufman. "Military Activities in the Exclusive Economic Zone: Preventing Uncertainty and Diffusing Conflict." California Western International Law Journal 32, no. 2 (2001): 268.

The geography of fisheries also shaped coalitions of interest. Conflicts between long-distance and coastal fishers were patterned by features of population ecology, including migration, growth rates, predator/prey relationships, and reproduction. The initial wave of territorial claims made by Latin American states were an effort to keep US fishers from depleting bait fisheries off the coasts of Costa Rica, Mexico, Panama, and Ecuador. US fishers captured baitfish to use in fishing for pelagic tuna in the Southeast Pacific. Eventually three states with productive tuna fisheries – Peru, Ecuador, and Chile – formed a coalition to strengthen and justify these claims.[707] Coalitions also formed between states whose coastlines represented a waypoint for highly migratory or anadromous fish species (most notably, tuna and salmon).[708]

The composition and distribution of technology also shaped interests in the emerging regime. 'Maritime states' with powerful navies or long-distance fishing fleets (especially the United States, Soviet Union, Japan, and Great Britain) preferred to maintain freedom of navigation and exploitation.[709] The technology of seabed mining was also influential in creating strong interests that preceded actual practice. Indeed, in the last six years of negotiations, seabed mining was "the only significant unresolved issue."[710] The contentious negotiations were pervaded by optimism about the impending affordability of deep-sea mining. The "Pioneer Seabed Miners" were a distinguishable, if not explicit, group of advanced states.[711] The location of seabed minerals in the center of ocean basins suggested an open-access regime, since no country could exclude the others,

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[707] Finley, *All the Fish in the Sea*.
[708] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 295.
[709] Ibid., 253–54.
[710] Ibid., 287.
[711] Beesley, "The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?," 189.

but the geographical variation between sites suggested exclusive mining rights because of the need for custom extraction platforms and the expense of mining technology.[712] Because of the enormous initial investment, venture capital mining corporations preferred the legal predictability of a nationalization scheme.[713] Developing countries who could not expect to afford deep-sea mining preferred a revenue sharing arrangement. States that exported minerals – such as Canada and Australia – had their own interests in limiting marine seabed mining.[714] The specific features of the International Seabed Authority that was eventually agreed upon will be reviewed in the next section.

In contrast to these strong common interests in exploitation, ideas about shared risk and vulnerability were under-developed and did not prompt the formation of coalitions. Problems associated with over-exploitation and pollution were too unknown or misunderstood to influence negotiations, as evidenced by the scant emphasis on over-exploitation and marine pollution. The proximate goals of the UNCLOS III negotiations related to the maintenance and advancement of existing use practices, more so than their control and regulation. The material context also limited what the regime could do in terms of enforcement, such that any strong regulatory regime would require the application of substantial effort and resources.

The final treaty was both ambitious and ambiguous. Most importantly, UNCLOS created a system of ownership and jurisdiction zones that specified who could legitimately access which resources. The political geography of UNCLOS includes zones with both horizontal and vertical dimensions. There are two vertical categories: the

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[712] Seyom Brown et al., eds., *Regimes for the Ocean, Outer Space, and Weather* (Washington: Brookings Institution, 1977), 83.
[713] Brown and Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," 879.
[714] Beesley, "The Negotiating Strategy of UNCLOS III: Developing and Developed Countries as Partners - A Pattern for Future Multilateral International Conferences?," 191.

seafloor and the water column. The horizontal seafloor is divided into two types of area. The resources of the continental shelf (up to 350 miles) belong to the nearest coastal state, and everything else is controlled by the International Seabed Authority, a public organization with a distributional mandate. The resources of the water column are divided into four types of zones: territorial sea, contiguous zone, Exclusive Economic Zone (EEZ), and high seas (also called the 'Area Beyond National Jurisdiction,' or ABNJ). The closer to the coastline, the more control a state has. The EEZ gives states exclusive control over water column resources, conditioned by the principle of free navigation for those who follow usage regulations mandated by the coastal state. These jurisdiction zones represent a "totally unprecedented array of boundary-making requirements," but did they effectively resolve all conflicts of interest and collective action problems?[715] In terms of reducing boundary conflicts, there is some support for a positive effect.[716] But, as discussed below, these zones have been less successful at resolving problems associated with pollution and over-exploitation.

[715] Douglas M Johnston, *The Theory and History of Ocean Boundary-Making* (Kingston: McGill-Queen's University Press, 1988), xi.
[716] Stephen C. Nemeth et al., "Ruling the Sea: Managing Maritime Conflicts through UNCLOS and Exclusive Economic Zones," *International Interactions*, July 29, 2014.

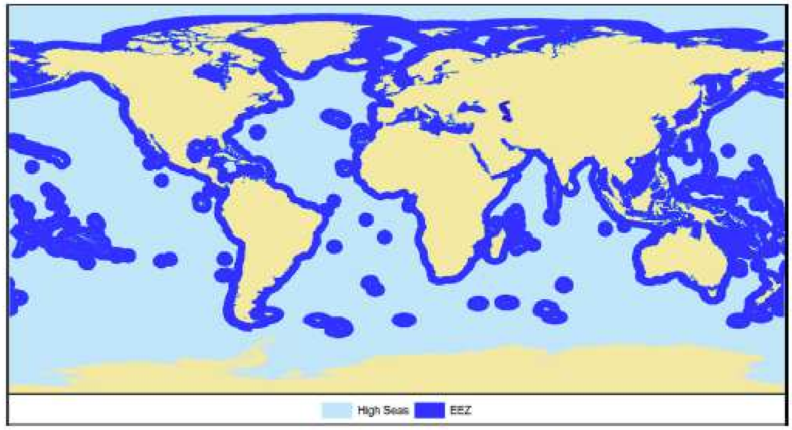

Fig. 1. Map of the global ocean showing Exclusive Economic Zones (EEZs) in dark shading and the high seas or areas beyond national jurisdiction in light shading. Map from the "*Sea Around Us*" Project, modified from data of the Maritime Boundary Database at the Flanders Marine Institute, Belgium, courtesy of Dirk Zeller, University of British Columbia.

Figure 13 - Exclusive Economic Zones, From Gjerde et al. "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction." Marine Pollution Bulletin 74, no. 2 (September 30, 2

International Seabed Authority

Negotiations over the Seabed Authority were some of the "most controversial and divisive" of the Third UNCLOS conference.[717] In 1967, Maltese representative Arvid Pardo gave a speech to the United Nations General Assembly (UNGA) declaring the seabed beyond national jurisdiction the "common heritage of mankind," a principle which was formally affirmed in UNGA Resolution 2749, adopted in 1970. The specific rules and norms that would fulfill this principle were an extremely contentious issue, and from 1977-1982 the terms of seabed mining were the "only significant unresolved issue" in the UNCLOS negotiations.[718] While developed countries preferred a 'first come, first served' regime, the Group of 77 (G77) developing countries preferred a model where exploitation occurred collectively, and benefits were shared. After the success of the 1973 OPEC embargo, the G77 coalition was "exhilarated, cohesive, and uncompromising" on

[717] Elizabeth R. DeSombre, *Global Environmental Institutions*, Global Institutions Series (London ; New York: Routledge, 2006), 81.
[718] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 287.

issues related to the creation of a more just and equitable international economic order.[719] These countries took the lead in formulating a blueprint for an international organization to manage seabed mining. The results in the final treaty represent "a creative compromise" between the G77 and developed country positions.[720]

Part XI of the final UNCLOS agreement covers activities in "The Area," the seabed beyond national jurisdiction. Section 4 creates a new international organization, the International Seabed Authority (ISA) to serve as the agent of UNCLOS treaty obligations. Headquartered in Kingston, Jamaica, the ISA became fully operational in 1996. It has several decision-making bodies, and the 36-member Council has an interesting means of ensuring representation of relevant parties. The members of the Council must be elected from within five different categories: the largest consumers of minerals (4 members), the largest investors in seabed mining (4 members), the largest exporters of minerals (4 members), developing countries with "special interests" such as large populations or land-locked status (6 members), and whatever countries need to be placed on the Council in order to achieve geographical representation (18 members). Geography and the distribution of technology therefore play an important role in determining the composition of the Council.

One of the most controversial aspects of the ISA is the 'Enterprise,' which is supposed to undertake actual exploitation of seabed minerals. The idea is that whenever an ISA member applies to explore or exploit seabed resources, it must choose two areas. The ISA then awards one of those areas to the applicant, and one to either the Enterprise

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[719] Ibid., 350.
[720] DeSombre, *Global Environmental Institutions*, 81.

or a developing country.[721] In part because of the delayed technological feasibility of seabed mining, the Enterprise has yet to be constituted.

The United States has failed to ratify UNCLOS, in large part because of its objections to the ISA. This may have come as a surprise to other UNCLOS members, because in 1976 Henry Kissinger, on behalf of the United States, made three explicit concessions on seabed mining. Kissinger claimed that the US would support the creation of the Enterprise, the principle of production control, and mandates for technology transfer.[722] The United States gave these concessions in order to "secure consensus on a treaty that protected certain navigation rights."[723] The United States got what it wanted, and the free passage norms of UNCLOS have become customary international law. In 1994, an implementation agreement to UNCLOS weakened the provisions for technology transfer and taxation and redistribution of mining profits, and strengthened the potential voting position of the United States within the Council.[724] Despite this acquiescence to US concerns about the ISA, the United States has still failed to ratify UNCLOS, and therefore does not participate in the ISA.

Regime Effectiveness

The complexity of the UNCLOS III negotiations, described above, makes it very difficult to provide an adequate and thorough explanation of why the international community settled on this particular regime. It is even challenging to explain the preferences of any single state throughout the conference period. The United States, for example, formulated its preferences through an inter-agency task force that represented

[721] Ibid., 82.
[722] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 361.
[723] Ibid., 380.
[724] Brown et al., *Regimes for the Ocean, Outer Space, and Weather*.

20 government agencies.[725] And domestic groups concerned with influencing the US position included “some 40 federal executive bureaus and agencies, some 33 congressional subcommittees, 3 states, and a wide range of commercial interests including fishing, oil and gas, and the merchant marine.”[726] Because the United States is a large state with multiple crosscutting interests, its position “shifted from a heavily maritime orientation to one that attempted to balance coastal with maritime interests.”[727] The above section illustrated the role of geography, technology, and ecology in shaping the negotiation coalitions. This remainder of the chapter considers two problems that the UNCLOS-centered regime has failed to solve: over-exploitation and marine pollution.

Figuring out why ocean management has been unable to achieve most of its core objectives is difficult, because human politics in the hydrosphere are characterized by a multitude of interests and parochial goals, including strategic, economic, and cultural imperatives. Ann Hollick concludes that the “international and domestic environment was not propitious for the negotiation of a balanced, comprehensive law of the sea regime.”[728] Part of the explanation is surely a lack of political will and enforcement capacity. A deeper, structural cause of ineffectiveness relates to the shifting foundations for governance: the ocean regime is, and has always been, based on incomplete, evolving, and often misguided understandings of what the ocean is, and what drives the expansion of ocean uses. This section outlines reasons for UNCLOS ineffectiveness that are based on geography, ecology, and technology. The ocean’s resources and networks exist on local, regional, and global scales. The magnitude of the management task presents many

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[725] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 351.
[726] Mark W. Janis, *Sea Power and the Law of the Sea*, Studies in Marine Affairs (Lexington, Mass: Lexington Books, 1976), 10.
[727] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 350.
[728] Ibid., 352.

challenges, which governance schemes overcome imperfectly. This section will first focus on whaling and fishing, as "one of the most glaring and high-profile examples of the mismanagement of the planet."[729]

Whaling

The attempt to achieve sustainable whale harvests is a unique case in the history of ocean governance, because of how early efforts began, and because of how spectacularly they failed. In 1946, the International Convention for the Regulation of Whaling established the International Whaling Commission (IWC), in recognition that "it is essential to protect all species of whales from further over-fishing." But the ultimate goal of the IWC was "orderly development of the whaling industry."[730] Despite overlap with the mandates of other international environmental agreements, the IWC remains "the central institution in the cetacean issue-area."[731] UNCLOS Article 65 merely reaffirms the obligation to cooperate for conservation of marine mammals, and in the case of whales to "work through the appropriate international organization for their conservation, management, and study," namely, the IWC.[732] The establishment of the EEZ did complicate IWC efforts, in that a larger number of coastal states began to assert unilateral rights to control coastal whale stocks.[733] But in general, the IWC is responsible for international whaling.

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[729] Smith, "The Industrialisation of the World Ocean," 21.
[730] International Convention for the Regulation of Whaling, 1946
[731] Peter John Stoett, "Cetapolitics: The IWC, Foreign Policies, and NGOs," in *The International Politics of Whaling* (Vancouver: UBC Press, 1997), 69.
[732] Denise Russell, *Who Rules the Waves? Piracy, Overfishing and Mining the Oceans* (London; New York; New York: Pluto Press ; Distributed in the United States of America exculsively by Palgrave Macmillan, 2010), 117.
[733] M.J. Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," *International Organization* 46, no. 1 (Winter 1992): 167.

Whales are a global resource, in that most whale species have a global range. Baleen whales, for example, migrate long distances between feeding and reproduction sites. Some whales have no particular migration path, but travel long distances "according to environmental conditions."[734] Most commercially fished whales have ranges that span the waters of multiple coastal states.[735] Whales are also a particularly vulnerable resource, in that their site-specific feeding and reproduction, and their frequent surfacing for air, make them easy targets for whaling ships. Slow reproduction rates, and the importance of healthy sub-populations for overall genetic diversity, mean that whales have low resilience to over-exploitation. The IWC has a unique advantage because it is "the only geographically global fishery commission."[736] Despite the global extent of IWC jurisdiction, it has a history of ineffective regulation.

Until the late 1960s, the IWC was basically a "whalers club."[737] There was a "relatively low sense of urgency" during this period, because the evidence of over-exploitation was not dispositive, and there was little public interest in whaling.[738] The UN Food and Agriculture Organization even encouraged the resumption and expansion of whaling after World War II, as "the quickest way to meet a severe global shortage of edible fats and oils."[739] Until the 1970s, quotas were determined with reference to the 'Blue Whale Unit,' or the amount of oil that could be produced by an adult blue whale. This pro-whaling orientation combined with a lack of clear scientific evidence regarding over-exploitation to create an ineffective control regime.

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[734] Russell, *Who Rules the Waves?*, 106.
[735] Arne Kalland and Brian Moeran, *Japanese Whaling: End of an Era?*, Scandinavian Institute for Asian Studies Monograph Series 61 (London: Curzon Press, 1992), 11.
[736] DeSombre, *Global Environmental Institutions*, 86.
[737] Kalland and Moeran, *Japanese Whaling*, 12.
[738] Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 158.
[739] Ibid., 159.

The IWC set a single global quota, undivided into individual state quotas, which encouraged competition and "reckless investment in larger and more efficient fleets," leading to the "overcapitalization of the pelagic whaling industry as a whole."[740] Information about whether the quota had been met came from whalers themselves, who had a disincentive to provide accurate data. In 1965, legal catches of baleen whales had to be over 38 feet long, yet "90 percent of the baleen whales caught were reported to be between thirty-eight and thirty-nine feet long, a statistical impossibility."[741] During the 1950s and 1960s, there was substantial reason to believe that quotas were too high, and that cheating was rampant.[742] But cetologists had neither the data nor the agreed-upon models required to make authoritative and persuasive statements about the status of whale stocks and the appropriate quota. Even if the data had been comprehensive and reliable, IWC members regularly assumed that fish-based population models were appropriate for managing whale populations.[743]

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[740] Kalland and Moeran, *Japanese Whaling*, 12.
[741] DeSombre and Barkin, *Fish*, 21.
[742] Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 161.
[743] Ibid., 160.

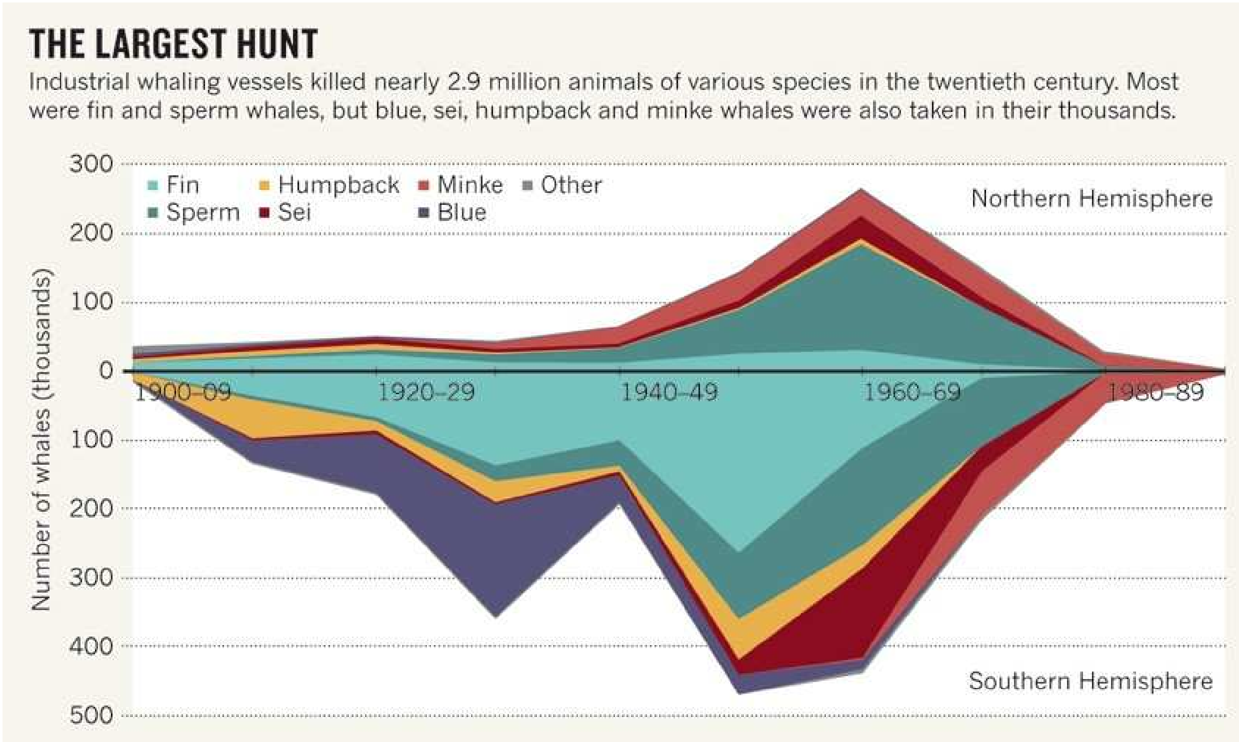

Figure 14 - History of global whale catch, From Cressey, Daniel. "World's Whaling Slaughter Tallied." Nature, March 11, 2015.

In the IWC, membership matters, in part because it is voluntary. Not all whaling states favored international regulation. Three of the biggest whaling countries – Japan, Norway, and the Soviet Union – joined the IWC in the late 1940s and early 1950s. Iceland joined, left in 1992, and rejoined in 2002. Latin American countries attempted to regulate commercial whaling for their own benefit. Chile made the first unilateral 200-mile claim in 1947 in part to protect its fledging whaling industry from post-war European competition.[744] When Chile, Ecuador, and Peru harmonized their 200-mile claims in 1952, they "banned all foreign fishing for baleen whales" and strictly regulated fishing for toothed whales.[745] By the 1960s and 1970s, the "large Japanese market for whale meat was supplied by Brazilian, Chilean, Icelandic, South Korean, Soviet, and

[744] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 75.
[745] Ibid., 86.

Taiwanese as well as Japanese firms."[746] Japanese customers bought whale meat from IWC members (Japan and Soviet Union), non-members (South Korea and Taiwan), and countries that would become members in the 1970s (Brazil and Chile). In the United States, a member since 1948, commercial whaling had basically ended before the 20th century.[747]

In the 1970s, major shifts in the membership and institutional structure of the IWC changed its approach to the management of whaling. In 1972, the Stockholm Conference adopted Resolution 33, calling for a ten-year moratorium on commercial whaling. The United States presented this idea to the IWC, where it was rejected.[748] Instead, in 1974 new procedures in the IWC Scientific Committee mandated the collection of more data and refinement of better models, in order to "raise the level of scientific argumentation that went into decision-making."[749] The 'Blue Whale Unit' was replaced with species-specific assessment and management.[750]A successful campaign by environmentalists and anti-whaling governments increased IWC membership during the late 1970s and early 1980s. Although many of these states joined for domestic reasons, their presence tipped IWC decision-making in favor of non-whaling states.[751] By 1982, 28 of 39 IWC members had no involvement in whaling.[752] In 1982, the IWC voted to introduce a moratorium on commercial whaling starting in 1986.

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746 Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 153.
747 Derek Thompson, "The Spectacular Rise and Fall of U.S. Whaling: An Innovation Story," *The Atlantic*, February 22, 2012.
748 I Miyaoka, *Legitimacy in International Society: Japan's Reaction to Global Wildlife Preservation* (Springer, 2013), 31.
749 Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 164.
750 Kalland and Moeran, *Japanese Whaling*, 12.
751 Stoett, "Cetapolitics: The IWC, Foreign Policies, and NGOs," 66.
752 Kalland and Moeran, *Japanese Whaling*, 13.

The moratorium on commercial whaling persists today, but its success has been incomplete because of several ways to avoid compliance. Japan and the Soviet Union continued commercial hunts into the late 1980s, and Norway and Iceland still hunt whales commercially. The IWC cannot force states to become or stay members, and Iceland left in 1992. When it re-joined in 2002, Iceland made an official reservation against the commercial moratorium. The IWC rules allow violations of policy in the case of formal objections, which Japan, Norway, Peru, and the Soviet Union filed immediately after the declaration of a commercial moratorium.[753] The Soviet Union, now Russia, has ceased commercial whaling, but former Soviet scientists revealed that "official state level catch statistics were intentionally incorrect during the Soviet era so that Soviet whalers could cover up non-compliance," including kills of protected species.[754] Another loophole is the exception for scientific whaling, which Japan, Iceland, and Norway have all claimed. Japan continues to cull hundreds of minke whales under scientific permits, but because the IWC requires that the carcasses be utilized, the whale meat is eventually sold. Because of the dubious scientific value of these whale kills, many observers have concluded that Japanese whaling "is clearly commercial whaling in the guise of scientific whaling."[755] Another exception is aboriginal subsistence whaling, which takes place in Greenland, Russia, the United States, and St. Vincent and the Grenadines. Proponents argue that aboriginal whaling is important to "retain cultural integrity," but the persistence of any kind of whaling may undermine the legitimacy of the IWC.[756]

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[753] Russell, *Who Rules the Waves?*, 108.; Miyaoka, *Legitimacy in International Society: Japan's Reaction to Global Wildlife Preservation*, 32.
[754] DeSombre and Barkin, *Fish*, 22.
[755] Russell, *Who Rules the Waves?*, 100.
[756] Stoett, "Cetapolitics: The IWC, Foreign Policies, and NGOs," 69–70.

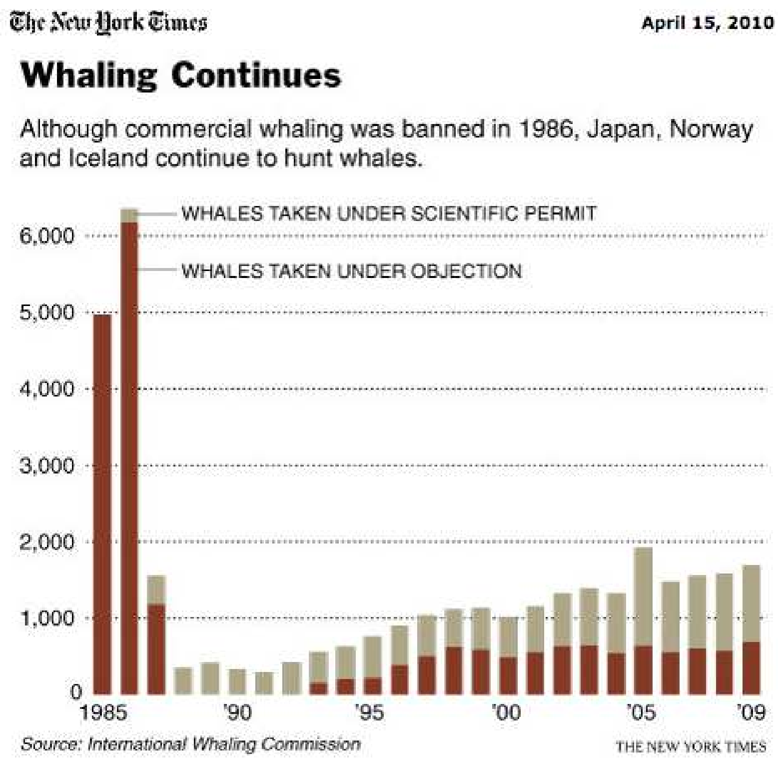

Figure 15 - Contemporary global whale catch, From Broder, John M. "U.S. Leads New Bid to Phase Out Whale Hunting." The New York Times, April 14, 2010.

The IWC had some success despite its weak enforcement structure. During the span of the Cold War, the IWC transitioned from a "whalers' club" to a pro-whale organization, and enacted a multi-decadal commercial moratorium. Although population data is extremely lacking across species, some whale populations and species have undoubtedly rebounded. The explanation for this change in regime norms and rules, and the resulting increased effectiveness of whale conservation, is related to the ecology of whales themselves. However, as M.J. Peterson argues in detail, cetologists did not operate as a persuasive, coherent, or authoritative influence on IWC policy during the period of change from 1974-1982; "the field was wide open for highly political and often highly public contention."[757] Although data collection had increased since the 1940s, disagreement persisted about the data requirements for new ecosystem-based modeling. The result was that the scientific group most knowledgeable about whales was unable to provide the IWC with "consensus expert advice."[758] Environmentalists filled the leadership void.

Environmental consciousness reached a new peak in the 1970s, and whales became "a metonym for the environment as a whole."[759] It was easy to portray whaling as intolerably cruel, because of their beauty, size, and hypothesized intelligence, and because "whaling kills whales slowly."[760] Environmentalists managed to strongly influence US policy in the IWC, and the United States took two sets of actions that secured victory for the commercial moratorium: it induced additional non-whaling states to join the IWC, and it threatened to impose trade sanctions on those who did not abide by the moratorium.[761] But anti-whaling environmentalists themselves helped generate a "normative snowball," by capturing publicity, lobbying through non-governmental organizations, and "[attracting] large numbers of highly educated individuals who legitimated their cause."[762]

The strength of the environmentalist argument is evident today, as "a return to large-scale whaling is almost unthinkable" and "remains unpalatable to world opinion."[763] After the 1986 commercial moratorium, preservationist arguments about the

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[757] Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 170.
[758] Ibid., 185.
[759] Kalland and Moeran, *Japanese Whaling*, 6.
[760] Russell, *Who Rules the Waves?*, 108.
[761] Peterson, "Whalers, Cetologists, Environmentalists, and the International Management of Whales," 173, 178, 181, 185.
[762] Stoett, "Cetapolitics: The IWC, Foreign Policies, and NGOs," 68, 96.
[763] Ibid., 77, 72.

immorality of whaling pervaded international meetings and media.[764] It is notable that environmentalist justifications persist despite belief in the early 1990s that "many marine mammal stocks appear to be both healthy and abundant."[765] Previously, extremely depressed whale population numbers brought conservationist and preservationist perspectives together. There is some evidence that some whale populations have rebounded, and yet anti-whaling generally persists. In earlier eras of the IWC, scientific uncertainty presented an opportunity for the whaling industry to assert its interpretations and interests. That uncertainty remains, and even the IWC is "reticent about recording the state of whale populations given the scientific uncertainty over numbers."[766] The anti-commercial whaling moratorium seems effective in part because humans have decided that killing whales is morally wrong; in other words, a normative value has been attached to a particular part of the ocean ecosystem. The rise in whale-watching tourism offers an economic alternative for coastal states, and its popularity reflects and reinforces an affective connection with whales.

If the IWC has become pro-whale instead of pro-whaling, in terms of its principles and institutional goals, then it has not been very effective. Whales now face a larger portfolio of risks than they did at the time of the IWC's founding. While hunting and bycatch have decreased, growth in global shipping traffic, and the size and speed of ships, has increased the risk of ship strikes. The impact of ship strikes on whales is difficult to quantify, because of detection, attribution, and reporting issues. Whales also have to deal with chronic risks, including chemical pollution, noise pollution, and habitat loss, which affect the general fitness of whales and whale populations.

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[764] Kalland and Moeran, *Japanese Whaling*, 3.
[765] Ibid., 5.
[766] Russell, *Who Rules the Waves?*, 109.

In terms of chemical pollution, industrial pesticides tend to bio-accumulate in cetaceans, weakening their immune systems and sometimes causing reproductive failure.[767] In May 2017, a dead killer whale that washed up in Great Britain was found to be contaminated with PCBs 100 times the amount known to cause physiological damage to whales. This particular whale came from the last resident pod of killer whales in Britain, which had not produced a healthy calf in 23 years.[768] Because whales are acoustic animals, noise pollution makes it difficult for them to navigate, communicate, locate prey, and (in the case of smaller whales) avoid predators.[769] Primary sources of marine noise include active sonar, explosions for oil and gas surveying, and ship motors, specifically the cavitation caused by their high-speed rotation.[770] The ambient noise causes chronic stress, and forces whales to compensate physiologically and behaviorally. Although these impacts are difficult to quantify, especially in terms of impact thresholds, the evidence is strongly suggestive. Immediately after the September 11th, 2001 terrorist attacks on the United States, the precipitous drop in shipping traffic caused a significant decrease in stress hormones among North Atlantic Right Whales.[771]

The IWC regulates the industry for the protection of the animal, but says or does nothing about the ocean environment. Its scientific data is insufficient for reliable population estimates in most cases, let alone an analysis of environmental stressors and ecosystem disruptions.

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[767] Ibid., 112.
[768] Damian Carrington, "UK Killer Whale Died with Extreme Levels of Toxic Pollutants," *The Guardian*, May 2, 2017.
[769] Russell, *Who Rules the Waves?*, 113.
[770] Peter L. Tyack, "Implications for Marine Mammals of Large-Scale Changes in the Marine Acoustic Environment," *Journal of Mammalogy* 89, no. 3 (July 2008): 549–58; Lidia Eva Wysocki, John P. Dittami, and Friedrich Ladich, "Ship Noise and Cortisol Secretion in European Freshwater Fishes," *Biological Conservation* 128, no. 4 (April 2006): 501–8.
[771] Jay Lindsay, "Unplanned 9/11 Analysis Links Noise, Whale Stress," *The Washington Post*, February 20, 2012.

Fisheries

One of the basic purposes of UNCLOS was the achievement of sustainable use of renewable ocean resources, by preventing their despoliation or over-exploitation.[772] Coastal states in particular had a strong incentive to protect their local resources, and this imperative drove the emergence of the EEZ concept among developing states. The creation of zones that gave "exclusive fishery management authority to states" was supposed to help combat over-fishing, by limiting entry, improving enforcement, and creating disincentives for over-capitalization.[773] The EEZ system brought 90 percent of the global marine fish catch under state control.[774] Yet by the 1990s, it was "abundantly apparent" that the regime for fishing had failed to prevent serial depletions, especially of high seas fisheries.[775] And the decreasing supply did not deter fishers; even as global fish catch declined, the capacity of the global fishing fleet had doubled since 1970.[776] Currently, roughly 80 percent of global fish stocks "can withstand no increase and may not even be able to sustain the level of fishing currently experienced."[777]

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[772] Koh, "A Constitution for the Oceans."
[773] Donna R. Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," *Journal of Transnational Law & Policy* 14, no. 1 (2004): 2–3.
[774] DeSombre and Barkin, *Fish*, 36.
[775] Michael Lodge and Satya Nandan, "Some Suggestions Towards Better Implementation of the United Nations Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks of 1995," *The International Journal of Marine and Coastal Law* 20, no. 3 (November 1, 2005): 346–47,.
[776] Brad Plumer, "The End of Fish, in One Chart," *The Washington Post*, May 20, 2012,; David Hunter, James Salzman, and Durwood Zaelke, *International Environmental Law and Policy* (New York; [St. Paul, Minn.]: Foundation Press ; Thomson/West, 2007), 761.
[777] DeSombre and Barkin, *Fish*, 4.

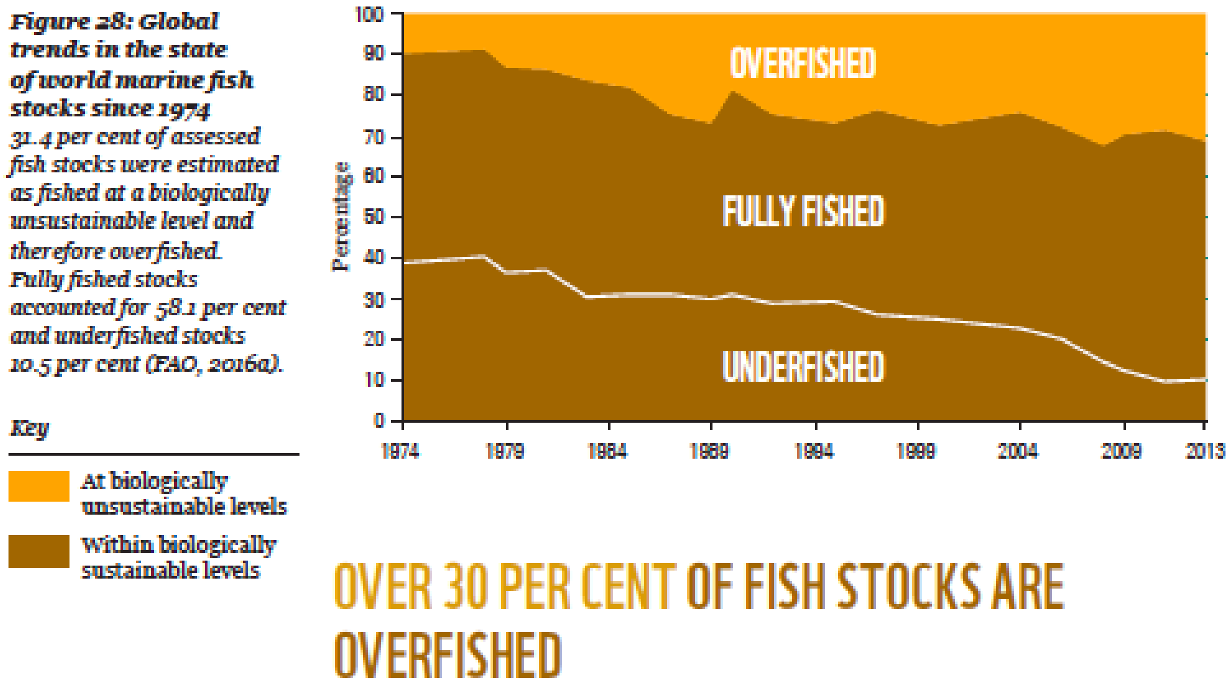

Figure 16 - Status of global fisheries, From World Wide Fund for Nature, Living Planet Report 2016: Risk and Resilience in a New Era., 2016.

Over-fishing is recognized as the "biggest failure" of the UNCLOS-centered governance regime.[778] In most cases, real efforts to restrain fishing are made only "after there is drastic and undeniable evidence of overexploitation."[779] The pro-fishing (as opposed to pro-fish) orientation should not be surprising, because fisheries interests drove the initial formation of the global fishing management regime.[780] Although the United States and Soviet Union are large coastal states, their relative technological superiority led their interests to align with the long-distance fishers. The result is a regime that is ineffective at achieving its goals of equitable distribution and sustainable use. In terms of sustainability, fisheries depletion, over-exploitation, and collapse have increased since the

[778] "In Deep Water," *The Economist*, February 22, 2014.
[779] B. Worm et al., "Rebuilding Global Fisheries," *Science* 325, no. 5940 (July 31, 2009): 583.
[780] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 375; Finley, *All the Fish in the Sea*.

negotiation of UNCLOS. In terms of equity, the coastal fisheries of developing countries are often subject to over-exploitation by long-distance fishers.[781]

Established explanations for this state of affairs include 'industry capture' of domestic and international policymaking, lack of political will and/or enforcement capacity in the high seas, and the hierarchical and complex structure of global fishing, the "ultimate industrial capitalist system."[782] Elizabeth DeSombre and Samuel Barkin suggest that the problem structure of the over-fishing problem is particularly challenging, because fisheries are subtractable, non-excludable, and 'first come, first served.' Effective policymaking is hindered by uncertainty about fish stocks, and "tensions between collective and individual incentives, and between long run and short run incentives."[783] These analyses are each insightful and collectively provide a thorough, but incomplete, explanation of the over-fishing problem.

A foundational criticism of the ocean governance regime concerns the disjuncture between the natural geography of fisheries, the geography of global technological systems, and the territorialized political geography of UNCLOS. This section will focus on the political geography created by UNCLOS, and especially the assumptions it makes about the geography and ecology of fisheries. The system of Regional Fisheries Management Organizations (RFMOs) will be described and evaluated in the following chapter, because many RFMOs were organized in the decades after UNCLOS, and

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[781] Daniel Pauly et al., "China's Distant-Water Fisheries in the 21st Century," *Fish and Fisheries* 15, no. 3 (September 2014): 474–88; Ramon Bonfil et al., "Distant Water Fleets : An Ecological, Economic and Social Assessment" (Fisheries Centre. University of British Columbia, 1998).

[782] J. Samuel Barkin and Elizabeth R. DeSombre, *Saving Global Fisheries: Reducing Fishing Capacity to Promote Sustainability* (Cambridge, Massachusetts: The MIT Press, 2013); Finley, *All the Fish in the Sea*, 8; DeSombre and Barkin, *Fish*; D. G. Webster, *Beyond the Tragedy in Global Fisheries*, Politics, Science, and the Environment (Cambridge, Massachusetts: The MIT Press, 2015); Russell, *Who Rules the Waves?*, 98.

[783] DeSombre and Barkin, *Fish*, 7.

because they adopt different management approaches compared to UNCLOS-based jurisdictions.

The UNCLOS regime assigns fisheries management authority to coastal states within their EEZs. In Article 61, states are assigned the prerogative to "determine the allowable catch," by "taking into account the best scientific evidence available." Article 61(c) clarifies that the goal is to maintain the "maximum sustainable yield," but qualified by environmental and economic factors, and taking into account the "special requirements of developing states." Article 62 requires the coastal state to make "the surplus of the available catch" accessible to foreign fishers, in order to achieve "optimum utilization" of EEZ fisheries. UNCLOS assumes and implies that setting quotas for the "allowable catch" is an effective management strategy.[784] It also assumes that access to foreign fishers can be documented and controlled. These provisions for fisheries management have been criticized as "largely ambiguous, incredibly flexible, and virtually unenforceable."[785]

UNCLOS jurisdiction zones ostensibly represent compromise between the free passage and territorial models of ocean governance, where jurisdiction is granted to coastal states within the EEZ, but other states are allowed 'innocent passage' and exploitation of any resources that do not exceed the 'maximum sustainable yield.' But in practice, it remains a 'freedom of the seas' situation for developed maritime states that can evade the insufficient surveillance and enforcement capacities of developing coastal states.[786] Long-distance foreign boats from Europe, Japan, China, and the United States quickly began encroaching on the EEZ fisheries of developing countries in Africa and

[784] Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 7.
[785] Ibid., 34.
[786] Ian Urbina, "Palau vs. the Poachers," *The New York Times*, February 17, 2016.

Latin America.[787] This outcome was made more likely because of the global technological systems present in the ocean: technological capabilities of access and exploitation far exceeded those of surveillance and enforcement at the time of treaty negotiation, and that basic asymmetry persists today.

Even costal states with the technical and financial capacity to effectively manage their coastal waters have failed; "proper management has been an afterthought…Exclusive national control has been the goal."[788] By nationalizing commercial fishing areas, UNCLOS created incentives to expand national fishing capacity. Most states, in declaring their EEZs, initially ejected foreign fishers from their national waters.[789] Many of these distant-water fishers returned to fish in their national EEZs, but there was often a "mismatch between national fleets and national stocks," such that national fleets were far too large for national fisheries.[790] For states without full capacity, subsidizing fishing activity was pursued as an easy economic development strategy, since fish produce themselves and only need to be harvested. In both cases, EEZs were "virtually open access for national fishermen."[791] The concept of 'allowable catch' was malleable due to lack of data, and many states used their discretion to set catch levels high enough to justify current practices.[792] In many EEZs, this increased fishing intensity merely "substituted a domestic tragedy of the commons for an

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[787] Milan Ilnyckyj, "The Legality and Sustainability of European Union Fisheries Policy in West Africa," *MIT International Review* 1, no. 1 (Spring 2007); Mary Kimani, "Safeguarding Africa's Fishing Waters," *Africa Renewal*, July 2009; Robert Evan Ellis, *China on the Ground in Latin America: Challenges for the Chinese and Impacts on the Region* (New York, NY: Palgrave Macmillan, 2014).
[788] Hollick, *U.S. Foreign Policy and the Law of the Sea*, 372.
[789] DeSombre and Barkin, *Fish*, 88.
[790] Barkin and DeSombre, *Saving Global Fisheries*, 134.
[791] Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 10.
[792] Ibid., 9–10.

international one."[793] Although the EEZ was designed to enable exclusion from fisheries, it ended up supporting the overall expansion of global fishing capacity.

A large part of the problem was the concept of 'rational fishing,' embodied in the notion of a 'maximum sustainable yield' (MSY). The MSY is the amount of fish that can be taken each year without decreasing the amount of fish available in future years, and it is used to determine the 'allowable catch.' Obviously, the MSY concept is an effort to translate the goal of sustainability into a rule or norm for fishing. MSY represents a theoretical catch limit, beyond which the reproductive rate of a given fishery declines and the catch becomes unsustainable. It is a fundamentally anthropocentric concept, because its primary concern is the value of the resource to human users, as opposed to a more general concern with ecological health.[794] The United States pushed strongly for the inclusion of the MSY concept in UNCLOS, in order to "reduce fishing by foreign fleets in US waters and to continue expansion of US distant water fleets."[795] Including MSY in fisheries management "made the world safe for distant-water fishing," by shifting the burden of scientific proof onto regulators.[796] MSY is a scientific concept that must be filled in with scientific content, but the data required is often lacking.

When MSY was enshrined in the UNCLOS regime, fisheries scientists were "enormously confident about their discipline."[797] The calculation of basic MSY requires information about population numbers and ages, lifespan, reproduction rates and breeding patterns. UNCLOS Article 61(3) also qualifies MSY based on "relevant

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[793] DeSombre and Barkin, *Fish*, 31, 89.; Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 35.
[794] Barkin and DeSombre, *Saving Global Fisheries*, 43.
[795] Webster, *Beyond the Tragedy in Global Fisheries*, 171.
[796] Finley, *All the Fish in the Sea*, 4.
[797] Ibid., 2.

environmental…factors," which might include predator-prey relationships, diffuse or indirect connections to ecosystem properties, and natural variability and change in each of these. Scientists often do not have the required information, which means that population models are rife with abstractions and assumptions. Because regulation typically only begins after a new species is exploited and then over-exploited, the relevant scientific data collection often lags the creation of the problem.[798] And it may be that ecosystems are simply too complicated for MSY: "Population dynamics within species and ecological relationships among species are too complex and involve too many scientific unknowns to model with the accuracy necessary to manage fisheries through precise quotas and other species-specific management tools."[799] The basic problem is that the MSY concept requires detailed maps of fish populations that marine scientists cannot produce with sufficient detail. And UNCLOS does not mandate good science either: "states have great flexibility and virtually no international legal obligation to base management on objective scientific criteria."[800] The result is a situation where MSY-based fisheries models are highly susceptible to biased interpretation.[801] The flexibility of MSY made it an effective tool for expanding industrial fishing.[802]

Besides lack of scientific support, the MSY concept has not been effectively integrated into fisheries management decision-making. Although it represents a maximum, MSY has often been interpreted as a target instead of a ceiling. And management targets have often been created at levels far above the advice of scientists. When deciding upon the MSY, managers rarely consider the contribution of dependent

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[798] Barkin and DeSombre, *Saving Global Fisheries*, 45.
[799] Ibid., 61.
[800] Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 10.
[801] Barkin and DeSombre, *Saving Global Fisheries*, 61.
[802] Finley, *All the Fish in the Sea*, 167.

and associated species for the resilience of a target species. So even if the relevant scientific information were available, and MSY models could accurately determine quotas that ensure a future sustainable yield, national and international fisheries managers still may not set effective targets.

The concept of MSY sits at the center of modern fisheries governance, but it has been criticized ever since the UNCLOS negotiations.[803] Proponents of reform suggest the "inherent uncertainty of fisheries," combined with the precautionary principle, means that the threshold of fishing must be lowered far below current calculations of MSY.[804] The MSY threshold would be reframed as "the point at which effort reduction policies should be applied."[805] While this reformulation of MSY would resolve some problems, there is another feature of the UNCLOS regime that obstructs effective fisheries management. The static political geography of the EEZ conflicts with the fluid and dynamic geography and ecology of the ocean. Ecologically, target species rely on ecosystem features and functions that span national borders. One of the obstacles to multi-species calculations of MSY is the fact that the EEZ does not 'fit' the scope of an interconnected ecosystem.[806] Philip Steinberg argues that this disconnection is exactly what makes the maritime political geographies durable: "lines drawn in and around ocean regions often take on an outsized level of authority because they are so self-evidently divorced from the matter that is experienced by those who actually inhabit the environment."[807] The same mismatch exists with the complex global fishing industry. Technologically, the interests

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803 Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 11.
804 Worm et al., "Rebuilding Global Fisheries," 583; Finley, *All the Fish in the Sea*.; Barkin and DeSombre, *Saving Global Fisheries*, 45, 50.
805 Christie, "It Don't Come EEZ: The Failure and Future of Coastal State Fisheries Management," 13.
806 Ibid., 14.
807 Philip E. Steinberg, "Of Other Seas: Metaphors and Materialities in Maritime Regions," *Atlantic Studies: Global Currents* 10, no. 2 (April 29, 2013): 162.

and practices related to fishing are global: a tuna sells for just as much whether it was caught inside or outside the EEZ. Even at the time of the UNCLOS negotiations, industrial-fishing fleets had global reach; their practices were not confined to regional or coastal spaces. This basic mismatch between political, natural, and technological geographies is a structural explanation for the failure of UNCLOS to achieve sustainable use of fisheries.

Marine Pollution

The vast ocean domain is plied by dirty industrial ships and bordered by industrial societies. It is easy to hide waste in the ocean, and for many decades ships discharged oil and dumped low-level nuclear waste without restriction. These practices were undertaken by two powerful vested interests: actors in the global oil market (extraction and shipping) and advanced militaries. The regulation of these harmful practices was weak and ineffective for many years. Only when the two international institutions for regulating marine pollution – MARPOL and the London Convention – changed their relationship to science and technology, did they achieve a degree of effectiveness with regard to reducing marine pollution.

MARPOL

The right to pollute was an "implicit freedom of the high seas" for many centuries, but in the 1920s marine pollution from industrialized and transnational shipping networks aroused international concern.[808] Regulation of oil emissions in the open ocean began with the first OILPOL agreement in 1954, which created zones where

[808] Vogler, *The Global Commons*, 57; Lynton Keith Caldwell, *International Environmental Policy: Emergence and Dimensions*, Second, Duke Press Policy Studies (Durham; London: Duke University Press, 1990), 294.

the discharge of oil was prohibited. But French and German scientists shortly developed a new consensus that, because of durability and harm of oil pollution at sea, such zones were insufficient.[809] Marine chemical pollution is especially damaging and dangerous, because it cannot be easily contained, it often resists biodegradation, and toxins increase in concentration as they move up the food chain.[810] The 1962 OILPOL amendments banned discharges from new tankers over 20,000 tons, but this rule "defined compliance in terms inconsistent with existing monitoring capabilities," and did not support the necessary infrastructure for port reception of what would otherwise be discharged.[811] The negotiation of MARPOL in the 1970s was a vast improvement over OILPOL, because it utilized new technology as part of the solution. Until MARPOL, other attempts to reduce marine pollution "had essentially no impact on improving the marine environment."[812]

MARPOL was negotiated under the aegis of the International Maritime Organization (IMO), which understands the treaty as "one of its most important accomplishments."[813] The first MARPOL agreement (1973), was opposed by "shipping interests in crucial maritime states," and did not receive enough ratifications to enter into force.[814] The United States created pressure for another meeting, during which MARPOL

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[809] Ronald B. Mitchell, *Intentional Oil Pollution at Sea: Environmental Policy and Treaty Compliance*, Global Environmental Accords Series (Cambridge, Mass.: MIT Press, 1994), 87.
[810] Caldwell, *International Environmental Policy: Emergence and Dimensions*, 294.
[811] Mitchell, *Intentional Oil Pollution at Sea*, 87.
[812] Ronald Mitchell, "Intentional Oil Pollution of the Oceans," in *Institutions for the Earth: Sources of Effective International Environmental Protection*, ed. Peter M. Haas, Robert O. Keohane, and Marc A. Levy, Global Environmental Accords Series (Cambridge, Mass: MIT Press, 1993), 245.
[813] DeSombre, *Global Environmental Institutions*, 75.
[814] Pamela S. Chasek, David Leonard Downie, and Janet Welsh Brown, *Global Environmental Politics*, Sixth edition, Dilemmas in World Politics (Boulder, Colorado: Westview Press, a member of the Perseus Books Group, 2014), 24.

was modified to assuage the concerns of opponents.[815] The eventual agreement fused with the previous one to become MARPOL 73/78.[816]

MARPOL 73/78 introduced design requirements for ships, including monitoring devices, separators (to reduce discharge), and segregated ballast tanks. The 1978 amendments to MARPOL added a requirement for washing out tanks with crude oil itself, instead of water. These facilitated new, less polluting practices related to ballast exchange and tank cleaning. MARPOL also shifted responsibility from operators, who manage at-sea discharges, to owners, who purchase constructed ships. These innovative regulatory provisions focused on the technology itself, thus shifting from enforcement at sea to enforcement in port.[817] Because MARPOL required ratification from enough states to account for more than one-half of global merchant shipping, by weight, it did not enter into force until 1983.[818] In 1997 the MARPOL conference of parties adopted a new protocol also focused on ship technology, which limits emissions of air pollutants and the sulfur content of fuels[819]

MARPOL is generally regarded as a success, despite continued challenges with implementation and enforcement in the developing world.[820] The treaty currently covers nearly 98 percent of registered global shipping, by weight.[821] More importantly than the scope of its membership, MARPOL "has fundamentally changed the way ships are built

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[815] DeSombre, *Global Environmental Institutions*, 74.
[816] Scott Barrett, *Environment and Statecraft: The Strategy of Environmental Treaty-Making* (Oxford ; New York: Oxford University Press, 2003), 264.
[817] J Wonham, "Some Recent Regulatory Developments in IMO for Which There Are Corresponding Requirements in the United Nations Convention on the Law of the Sea. A Challenge to Be Met by the States Parties?," *Marine Policy* 20, no. 5 (September 1996): 377–88.
[818] Kate O'Neill, *The Environment and International Relations*, Themes in International Relations (Cambridge, UK ; New York: Cambridge University Press, 2009), 81.
[819] "Submission of MARPOL Protocol to the U.S. Senate," *The American Journal of International Law* 97, no. 4 (October 2003): 979–80.
[820] Md. Saiful Karim, "Implementation of the MARPOL Convention in Developing Countries," *Nordic Journal of International Law* 79, no. 2 (April 1, 2010): 303–37.
[821] DeSombre, *Global Environmental Institutions*, 74.

and has dramatically decreased the extent of oil pollution."[822] Violations are virtually nonexistent.[823] As carefully argued by Ronald Mitchell, the shift from performance standards to equipment standards significantly explains MARPOL's success, because it "removed practical and legal barriers to effective detection and enforcement."[824] Port-based enforcement was both empowered and made easier by MARPOL, which "radically changed the nature of the compliance problem."[825]

Mitchell and others argue that the evolution from OILPOL, to MARPOL, to MARPOL 73/78, is an example of regime learning.[826] Mitchell says that the choice of equipment standards "was a response to the perceived failure of the existing performance standards." A crucial element of this learning process was the shock of highly visible oil spills, and their effect on public opinion.[827] The *Torrey Canyon* spill off Britain in 1967, and the *Amico Cadiz* spill off France in 1978, "dramatically highlighted the disastrous environmental effects of oil pollution on the marine life of the area, as well as on the fishing and tourist industries."[828] But the ultimate reason for MARPOL's success in reducing marine oil pollution is the changes made to the global technological system of transnational oil shipping. The crude oil washing technique required by MARPOL 73/78 "had been available since the late 1960s." Due to the political momentum behind stricter equipment standard proposals, the oil industry "reevaluated its technological options" and

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[822] Ibid., 75.
[823] Mitchell, "Intentional Oil Pollution of the Oceans," 246.
[824] Ibid.
[825] Barrett, *Environment and Statecraft*, 264.
[826] Mitchell, "Intentional Oil Pollution of the Oceans," 228; O'Neill, *The Environment and International Relations*, 127.
[827] Mitchell, "Intentional Oil Pollution of the Oceans," 245–46.
[828] Caldwell, *International Environmental Policy: Emergence and Dimensions*, 145.

proposed crude oil washing. [829] This is a case of a regime targeting technological systems directly, and mandating the use of easily verified safety technology.

The MARPOL regime is lauded for scope, which includes acute accidents and mundane discharges, and which has expanded to include atmospheric emissions.[830] But the treaty does not cover land-based sources of pollution, which are more significant in terms of overall harm to the marine environment.[831] MARPOL's political geography is not shaped by the dimensions of the problem, but by the form of solution: because the IMO handles the issue, a coordinated approach to marine pollution that involves sea- and land-based sources is highly unlikely.[832]

London Convention

In the early Cold War, a new source of contamination began to weigh on the minds of policymakers, scientists, and eventually the general public: radioactivity. Precisely characterizing the risks involved took several decades. In 1961, the US Department of Health, Education, and Welfare reported that "very little is known about the effect on animals or humans of very low, but prolonged exposures" to radiation.[833] Throughout the early Cold War, the scientific debate about the dangers of nuclear 'fallout' and radiation existed alongside a political debate about the ability of national militaries to release nuclear material into the environment through testing weapons and dumping waste. A subset of this international and domestic contention concerned the question of dumping nuclear waste at sea.

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[829] Mitchell, "Intentional Oil Pollution of the Oceans," 214.
[830] Paine, *The Sea and Civilization*, 592.
[831] Vogler, *The Global Commons*, 56.
[832] Oran R Young, *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale* (Cambridge, Mass.: MIT Press, 2002), 117.
[833] Aaron Nisenson, "The Great Fallout Controversy," *JAMA: The Journal of the American Medical Association* 181, no. 2 (July 14, 1962): 171.

The United States was the first to dump nuclear waste in the ocean, in 1946. Great Britain, Japan, and the Soviet Union soon followed in the 1950s.[834] Throughout the Cold War, fourteen countries dumped radioactive waste into the ocean, with almost 90 percent coming from Great Britain and the Soviet Union.[835] In addition to emitting nuclear waste into rivers that flow into the ocean, the Soviet Union dumped 18 spent nuclear reactors directly into the ocean.[836] The United States also relied on sea disposal until the early 1960s. This practice was justified by scientists in the United States and Great Britain, while the Soviet Union denied its own dumping. For the first few decades, the structure of the problem was uncertain and contested, and scientists from different disciplines each contributed ideas about the level of harm. The idea of a "threshold value" – a determinable limit beyond which dumping becomes harmful – prevailed throughout this period, and served as a "benchmark of safety" for disposal rates.[837] Geneticists criticized threshold values as unscientific from the beginning, while other scientists forwarded the idea of a "tolerable dose" or "permissible dose" below which "no damage would occur."[838] Health physicists, especially in Great Britain, adopted a "critical pathways" approach to calculating permissible dose, which focused on the amount of radiation that humans might consume from marine products, and ignored other effects on the marine environment.[839]

Oceanographers, initially stymied by "enormous uncertainty about the behavior of the sea," supported and provided threshold values in the 1950s (and added the term

[834] Jason H. Eaton, "Kicking the Habit: Russia's Addiction to Nuclear Waste Dumping at Sea.," *Denver Journal of International Law and Policy* 23, no. 2 (1995): 292.
[835] Hamblin, *Poison in the Well*, 252–53.
[836] Kristin Moody-O'Grady, "Nuclear Waste Dumping in the Oceans: Has the Cold War Taught Us Anything," *Natural Resources Journal* 35, no. 3 (1995): 697.
[837] Hamblin, *Poison in the Well*, 5.
[838] Ibid., 14–15.
[839] Ibid., 139.

“acceptable dose,” undefined).[840] Despite the irreversibility of sea disposal, oceanographers and other scientists did not challenge the prevailing view of the ocean as “a giant sewer with a specific capacity.”[841] They lacked baselines for marine radioactivity, as ocean nuclear testing preceded data collection.[842]

An anti-dumping consensus slowly formed as oceanographers accumulated knowledge, and effectively leveraged their position with the US government. Discoveries about ocean circulation during the 1957-58 IGY dispelled the notion of stagnant zones where radioactive waste could be isolated. A new collective action problem emerged, and the support for sea disposal weakened. The United States, facing internal and regional pressure, stopped sea disposal of nuclear waste in the early 1960s. The emergence of a global environmental movement, energized by Stockholm in 1972, rapidly ‘turned the tide’ of public opinion against sea disposal during the 1970s.[843] Yet several countries continued to dispose of radioactive waste in the ocean until the early 1990s. Russia, in particular, continued dumping, in the stated belief that the practice is not harmful.[844]

Military interest in maintaining the practice, instead of identifying the problem, impeded the accumulation of scientific knowledge crucial for avoiding dangerous levels of marine radioactivity. The government listened to scientists who lacked domain-specific knowledge. Health physics requires broad knowledge in “physics, electronics, biophysics, chemistry, biochemistry, physiology, genetics, toxicology, and ecology,” but these scientists and “sanitary engineers” had no knowledge of ocean circulation and

[840] Ibid., 34–36., 137
[841] Ibid., 29.
[842] Ibid., 87.
[843] Ibid., 244.
[844] Eaton, “Kicking the Habit: Russia’s Addiction to Nuclear Waste Dumping at Sea.,” 296.

bioaccumulation.[845] And, the “critical pathways” approach artificially narrowed the domain of negative consequences by excluding broader environmental effects. Because of scientific uncertainty and misplaced scientific authority, the governments of nuclear powers could easily challenge opponents of dumping, and marshal proponents (or at least neutral scientists).

The 1972 London Dumping Convention, negotiated under the auspices of the IMO, prohibited the dumping of high-level radioactive waste, among other controlled substances. In some senses, the London Convention was a success. It was the first agreement to empower coastal states to enforce provisions, although a weakness is that the London Convention does not empower the IMO or International Atomic Energy Agency to monitor or enforce its rules.[846] Before the agreement, the dumping of “municipal and industrial waste” was very common, and after the London Convention, acceptance of waste dumping has “decreased dramatically.”[847]

In terms of nuclear waste, the 1972 London Convention was only partially successful. It ignored the full extent of disposal practices, by treating radioactive disposal as an ocean-only problem. The London Convention prohibited the dumping of radioactive waste from ships, but most of Great Britain’s waste disposal happened through pipelines that emptied on to its coastline, and much of the Soviet discharge entered the Arctic Ocean through its north-flowing rivers.[848] The London Convention also banned only “high-level waste,” which actually created “internationally accepted

[845] Hamblin, *Poison in the Well*, 140.
[846] Chasek, Downie, and Brown, *Global Environmental Politics*, 24; Caldwell, *International Environmental Policy: Emergence and Dimensions*, 146.; Moody-O’Grady, “Nuclear Waste Dumping in the Oceans: Has the Cold War Taught Us Anything,” 706.
[847] DeSombre, *Global Environmental Institutions*, 76.
[848] Hamblin, *Poison in the Well*, 221.

threshold levels to legitimize dumping."[849] In 1983, the Convention initiated a ten-year moratorium on "depositing slightly or moderately radioactive substances in the sea," and in 1993 this moratorium became a formal ban.[850] Russia violated both the moratorium and the formal ban, and although it claims to have ceased dumping, there is disagreement about the veracity of that claim.[851]

Conclusion

The collective problems and shared vulnerabilities surveyed in this chapter demonstrate that the ocean governance regime tends to be ineffective when it ignores the contours and patterns of the ocean environment and the technological systems that exploit it. In general, the scope of "regime arrangements are arbitrarily defined without reference to the boundaries of natural systems."[852] The political geography of UNCLOS is fragmented into seabed and water column, EEZ and ABNJ, which makes integrated management inherently difficult. When resources like whales and fish are far from shore, and the technology of access is cheap and de-centralized, regulating exploitation is more difficult. The strongest examples of success include regulation of technological systems and the targeted collection and dissemination of information about ecosystems. The environmental movement played an important role in both cases, by increasing the visibility of information about the harms of whaling and marine pollution.

[849] Ibid., 249.
[850] Moody-O'Grady, "Nuclear Waste Dumping in the Oceans: Has the Cold War Taught Us Anything," 700; Vogler, *The Global Commons*, 60.
[851] Katherine Jacobsen, "Russia's Nuclear Nightmare Flows down Radioactive River," *Associated Press*, April 29, 2016; Eaton, "Kicking the Habit: Russia's Addiction to Nuclear Waste Dumping at Sea."
[852] Vogler, *The Global Commons*, 46.

Planetary Ocean: Geophysical, Ecological, and Technological Horizons

The way humans use and understand the ocean changed significantly in the years following the United Nations Convention on the Law of the Sea (UNCLOS). By the late 20th century, holistic conceptions of nature combined with increasingly global data sets to produce a new dominant paradigm for scientific study of the planet: Earth system science.[853] The basic principle of Earth system science is the integration of models and theories of change, at all scales. The ocean is now understood as a highly complex, interdependent, and dynamic planetary environment with meaningful interactions across geophysical layers, including the ocean/atmosphere interface, and between ecological and geophysical systems. Through concerted and coordinated effort, several areas of oceanography are becoming data rich for the first time.[854] New tools of sampling and remote sensing are diversifying the sources and types of information collected. Enabling technologies such as Geographic Information Systems support the production of better maps of the ocean. Collective endeavors like the World Ocean Census, Ocean Biogeographic Information System, and Global Ocean Observing System actively seek out new data and ensure its global dissemination. This influx of data and knowledge stokes much unbridled optimism; some scientists suggest that we are approaching "predictive capabilities" in terms of our understanding of ocean systems.[855] But this conclusion seems premature, as "very little of the ocean has been scientifically

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[853] Earth System Sciences Committee NASA Advisory Council, *Earth System Science Overview : A Program for Global Change* (Washington, D.C: National Aeronautics and Space Administration, 1986).
[854] Deborah Ann Glickson et al., eds., *Oceanography in 2025: Proceedings of a Workshop* (Washington, D.C: National Academies Press, 2009).
[855] Ibid., 153.

investigated."[856] This situation – major leaps in knowledge but with significant gaps remaining – sets the stage for ocean governance in the 21st century.

This chapter begins by surveying the contemporary status of marine scientific knowledge and maritime technology. Although much remains unknown, data collection and theory building has revealed new environmental problems and created new economic interests. Advances in technological capability have amplified existing uses, especially global-scale fishing. The second section reviews augmentations of the ocean governance regime starting in the 1990s, which sought to improve and build upon the framework created by the United Nations Convention on the Law of the Sea (UNCLOS). The third section describes several areas where the ocean governance regime fails to achieve its goals, and explains these instances of ineffectiveness by reference to a mismatch between the material context and the ocean governance regime. Because this chapter explores the contemporary period, the potential topics of consideration are numerous. But new technologies heralded as on the near-term horizon may not develop in the manner or with the speed that is predicted. And it is possible that the ocean governance regime will adjust to account for new uses. This chapter therefore confines the areas of analysis to those where the ocean governance regime has established a clear goal, such as reducing marine pollution or achieving sustainable fishing, which it fails to achieve.

Oceanography

In terms of geophysical knowledge, both the seafloor and water column remain starkly under-sampled. The most synoptic maps of the seafloor are low resolution, produced by satellites that measure sea surface height as a proxy for gravitational

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[856] Darlene Trew Crist, Gail Scowcroft, and James M. Harding, *World Ocean Census: A Global Survey of Marine Life* (Richmond Hill, Ont. ; Buffalo, New York: Firefly Books, 2009), 15.

variation. More detailed acoustic sensing still gathers information about the seafloor at bicycle-speed.[857] The interaction between water circulation and seafloor composition is increasingly understood; processes of sediment suspension, transport, and deposition interact with the winds, waves, and tides.[858] But the details of ocean circulation are relatively uncertain; the paradigm of macro-dominant ocean circulations was only replaced by a theory of meso-scale dynamics in the 1990s.[859] Physical oceanographers are just beginning to understand the ways that marine ecology affects ocean circulation.[860] Computer models produce seemingly synoptic dynamic maps, but often belie gaps in knowledge.

Research on ocean ecology, under-emphasized in previous eras, received a boost from the environmental consciousness of the 1970s. [861] But a disproportionate amount of data still comes from ocean users; for example, fish population estimates often rely on self-reported catch numbers.[862] Even with better data collection, inferences are limited; without a "zero year baseline" there is no way to accurately gauge the magnitude of the impact from human depredations.[863] Still, marine scientists are attempting to establish contemporary baselines, so that the size, rate, and direction of change in ocean ecosystems can be measured from now on.[864] The result has been a series of important discoveries, including both new species and new and distinctive ecosystems; marine

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[857] Xiaowei Wang, "Ocean Sensing: Interview with Dawn Wright," *Harvard Design Magazine*, Fall/Winter 2014.
[858] Timothy A. Kearns and Joe Breman, "Bathymetry - the Art and Science of Seafloor Modeling for Modern Applications," in *Ocean Globe* (Redlands, CA: ESRI Press Academic, 2010), 7.
[859] Glickson et al., *Oceanography in 2025*, 53.
[860] Laura Geggel, "Multitudes of Mighty Sea Monkeys Move Oceans, Study Says," *The Christian Science Monitor*, September 30, 2014.
[861] Jacob Darwin Hamblin, *Oceanographers and the Cold War: Disciples of Marine Science* (Seattle: University of Washington Press, 2005).
[862] Crist, Scowcroft, and Harding, *World Ocean Census*, 28.
[863] Ibid., 65.
[864] Ibid., 57.

ecologists now recognize that “the ocean everywhere is alive.”[865] Marine scientists in the 2010 World Ocean Census found that “rare is common,” and discoveries were easy to come by.[866] The diversity they characterize – of ecosystem types, species within an ecosystem, and organisms within a species – is understood to be critical to ecological resilience. Marine scientists are also uncovering how basic physical conditions throughout the ocean “control the abundance, distribution and composition of biological life.”[867] The interdisciplinary science of ‘marine landscape ecology,’ which emerged in the 1980s, focuses on the composition, configuration, and complexity of the ‘seascape’ and its impact on ecological processes at all scales.[868] This connection between geophysical and ecological features of the planetary ocean represents the ideal integrative picture of Earth system science.

Brave New Ocean

Contemporary scientific knowledge of the marine environment has uncovered new collective action problems. Most visible are the uses and over-uses of the ocean as a sink for the outputs of global production processes: chemicals, plastics, carbon dioxide, and heat. Chemical fertilizers (phosphorous and nitrogen) run from farmland into rivers, and from rivers into oceans. The “synthetic disaster” of hundreds of ‘dead zones’ around the world is caused when these fertilizers cause algae blooms, and then massive die offs,

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[865] A quarter of a million species of marine life have been identified, and fifteen thousand of those are fishes. Most of this known ocean life is clustered on the continental shelves, which represent only ten percent of the seafloor. Species are classified by horizontal (coastal, littoral, migratory) and vertical location (benthic, demersal, and pelagic); Crist, Scowcroft, and Harding, *World Ocean Census*, 12.
[866] Ibid., 230.
[867] Edward T. Game et al., “Pelagic Protected Areas: The Missing Dimension in Ocean Conservation,” *Trends in Ecology & Evolution* 24, no. 7 (July 2009): 363.
[868] Erik C. Franklin, “Marine Landscape Ecology of Coral Reefs Emerges from Developments in Seafloor Mapping, GPS, and GIS,” in *Ocean Globe* (Redlands, CA: ES, 2010).

and then hypoxia.[869] This problem is well understood, and the practices that cause it are land-based. Other forms of pollution enter the ocean after being blown there by the wind, or washed off the coastline. Farther out to sea, the "detritus of civilization" is driven by surface circulation and gathers in large gyres.[870] Five of these "debris collection zones" have been identified, and 60 to 80 percent of the debris is plastic.[871] This debris, and especially photo-degraded micro-plastics, concentrate toxins, block sunlight, and are consumed by fish. The complete structure of this problem remains opaque, because the full extent of the impact is uncertain. We do not fully know where debris goes, or how much there is. The prevailing notion of "basins of attraction" is insufficient for locating and understanding the dynamics of the great ocean 'garbage patches'.[872]

While these chemical and material inputs create obvious and visible problems, three more diffuse and significant threats are coming into focus. Physical oceanographers have broadened the concept of 'climate change' to include ocean warming, ocean acidification, and sea-level rise. As atmospheric temperatures rise, the ocean absorbs more heat. Ocean warming causes problems like coral bleaching and alterations in species distribution.[873] As species' ranges change in response to warming oceans, diseases spread to new places and populations. The ocean also absorbs excess atmospheric CO^2 because of molecular exchange at the interface of ocean and air, which

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[869] Jon Bowermaster, ed., *Oceans: The Threats to Our Seas and What You Can Do to Turn the Tide: A Participant Media Guide*, 1st ed (New York: PublicAffairs, 2010), 136.
[870] "The Environmental Outlook: Rising Levels of Garbage In The World's Oceans," *The Diane Rehm Show*, November 4, 2014.
[871] Jennifer Gabrys, *Program Earth: Environmental Sensing Technology and the Making of a Computational Planet*, 2016, 141.
[872] Gary Froyland, Robyn M. Stuart, and Erik van Sebille, "How Well-Connected Is the Surface of the Global Ocean?," *Chaos: An Interdisciplinary Journal of Nonlinear Science* 24, no. 3 (September 2014): 033126.
[873] C Nellemann et al., *In Dead Water: Merging of Climate Change with Pollution, over-Harvest, and Infestations in the World's Fishing Grounds* (Arendal, Norway: United Nations Environment Programme, GRID-Arendal, 2008); Erica Goode, "Fish Seek Cooler Waters, Leaving Some Fishermen's Nets Empty," *The New York Times*, December 30, 2016.

acidifies the water and thereby reduces the saturation of calcium carbonate minerals, harming the construction of shells and skeletons for marine microorganisms. Sea-level rise is also a geophysical phenomenon caused by glacial melting and thermal expansion of seawater.[874] The extent of the problem has been hard to ascertain, because baselines for understanding change are young: satellite altimetry measurements of sea level began in 1994, and adequate ice measurements only in 2004.[875] Although scientists know that the ocean is the primary sink for both carbon dioxide and atmospheric heat, the dynamics of these processes are poorly understood.[876]

Another emerging collective action problem relates to a newly understood interest in ‘ecosystem services.’ This concept emerged as scientists began to understand the ways that a stable and normal-functioning ecosphere contributes to habitable planetary conditions for humans: a strong collective interest, and potential shared vulnerability. But the specifics of this interest remain unclear: oceans drive all major Earth processes, but we do not entirely understand how.[877] The ecosystem services concept requires the challenging task of defining diffuse causal relationship and attaching value to them. The integration of economics and ecology this implies faces many barriers, including insufficient information about the relationship between ecosystem structures and functions, and disagreements about valuation.[878]

Despite the general paucity of baseline data, scientists do know that ocean ecosystems are changing in response to the intensity of human activities. These activities

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[874] Vivien Gornitz, *Rising Seas: Past, Present, Future* (New York: Columbia University Press, 2013), 159.
[875] Glickson et al., *Oceanography in 2025*, 48.
[876] Gabrys, *Program Earth*, 146.
[877] Bowermaster, *Oceans*, 12.
[878] Stephen Polasky and Kathleen Segerson, “Integrating Ecology and Economics in the Study of Ecosystem Services: Some Lessons Learned,” *Annual Review of Resource Economics* 1, no. 1 (October 10, 2009): 409–34.

are causing an unprecedented amount of disruption in the ocean ecosphere; today, "humans alter multiple abiotic and biotic environmental controls at rates, scales, and combinations fundamentally different from those at any other time in history."[879] The general consensus is that the planetary ocean is experiencing a radical ecological simplification as a result of the "synergistic effects of habitat destruction, overfishing, introduced species, warming, acidification, toxins, and massive runoff of nutrients."[880] Existing ocean ecosystems are deemed on "the point of collapse."[881] Distinctive ecosystems in the deep ocean are especially vulnerable to permanent damage, because they are marked by slow growth, maturation, and reproduction.[882] A sense of urgency exists among scientists who study places that are undergoing fundamental transformation, such as in the polar oceans.[883] The "brave new ocean" is not ideal for human interests, but may be inevitable.[884] Any possible solutions "need to be urgent, focused, innovative and global."[885]

New Resources

Increased scientific understanding of the marine material context has identified new problems, but also generated new interests in exploitation. In particular, research on deep-sea ecosystems has revealed new resources. Unique communities of organisms endemic to seamounts, hydrothermal vents, and cold seeps represent genetic resources of

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[879] Helenmary M. Hotz, "Developing Nearshore Bathymetry to Analyze a Noxious Seaweed along the South0facing Shore of Harwich, Capoe Cod, Massachusetts," in *Ocean Globe*, ed. Joe Breman (Redlands, CA: ESRI Press Academic, 2010), 233.
[880] J. B. C. Jackson, "Ecological Extinction and Evolution in the Brave New Ocean," *Proceedings of the National Academy of Sciences* 105, no. Supplement 1 (August 12, 2008): 11458.
[881] "From Decline to Recovery: A Rescue Package for the Global Ocean," Summary Report (Global Ocean Commission, 2014).
[882] K. J. Mengerink et al., "A Call for Deep-Ocean Stewardship," *Science* 344, no. 6185 (May 16, 2014): 697.
[883] Crist, Scowcroft, and Harding, *World Ocean Census*, 117.
[884] Jackson, "Ecological Extinction and Evolution in the Brave New Ocean."
[885] Tony J. Pitcher and William W.L. Cheung, "Fisheries: Hope or Despair?," *Marine Pollution Bulletin* 74, no. 2 (September 30, 2013): 506–16.

interest to medical research and pharmaceutical manufacturing.[886] The new activity of 'bio-prospecting' for marine genetic resources at these sites lacks any kind of regulatory regime. These same locations contain important minerals, which were already known to be present in seafloor manganese nodules, but appear in different concentrations and compositions around vents and seeps. The work of geologists studying the seafloor has revealed that manganese nodules, which had been known to contain nickel, copper, and cobalt, also contain increasingly valuable rare Earth elements.[887] These additional incentives for deep-sea mining may finally be aligning with the technological capability to exploit them: exploratory licensing from the International Seabed Authority has experienced a boom in recent years (26 total issued, 18 since 2011).[888] While neither type of deep-sea resource has yet to be really exploited, when and if interests in bio-prospecting and deep-seabed mining evolve into practices, they may conflict. Slow-growing and unique biotic communities are unlikely to recover quickly from the sediment plumes and toxic releases of seabed mining.[889]

Fishing Technology

Fishing practices have continued to grow and create more severe versions of the same problems: over-exploitation and habitat destruction. Advanced technological capability drives these practices, and the problem they cause is disruption of productive ecosystems. The amount of fish caught worldwide peaked in 1996, and has declined ever

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[886] "In Deep Water," *The Economist*, February 22, 2014; Salvatore Aricò, ed., *Ocean Sustainability in the 21st Century* (Cambridge: Cambridge Univ. Press, 2015), 203.;John Vogler, "Global Commons Revisited," *Global Policy* 3, no. 1 (February 2012): 67.
[887] Maddie Stone, "The Future of Technology Is Hiding on the Ocean Floor," *Gizmodo*, April 5, 2016.
[888] L. M. Wedding et al., "Managing Mining of the Deep Seabed," *Science* 349, no. 6244 (July 10, 2015): 144–45.
[889] Charles W. Schmidt, "Going Deep: Cautious Steps toward Seabed Mining," *Environmental Health Perspectives* 123, no. 9 (September 1, 2015): A234–41; Thomas A. Schlacher et al., "Seamount Benthos in a Cobalt-Rich Crust Region of the Central Pacific: Conservation Challenges for Future Seabed Mining," ed. David Richardson, *Diversity and Distributions* 20, no. 5 (May 2014): 491–502.

since. This is not for lack of effort, which has increased significantly in the last 30 years, but because the majority of fisheries are over-exploited.[890] It is difficult to rebuild depleted populations that contain fewer mature adults, because of their depressed reproduction rate. There has been a "dramatic expansion" in the types of fish caught.[891] This is all enabled by the scale and sophistication of contemporary fishing technology. 40,000 industrial fishing boats use trawls and seine nets to scour farther out and deeper down than ever before.[892] Old technologies (vessels, nets, long-lines) have been significantly improved, and new technologies deployed in the last three decades. Spotter airplanes locate schools of fish, and more than 50,000 'fish aggregation devices' have been deployed in the Pacific Ocean alone.[893] Not only do these methods facilitate the extraction of large numbers of fish, they often destroy benthic habitats wholesale. Deep-sea fishing in particular has been described as a kind of "fish mining," where a theoretically renewable resource is so heavily exploited that it becomes functionally non-renewable.[894]

The global economy of fisheries practices is highly complex, and defined by the geography of technology and ecosystems. In one way, it is de-centralized. Fishing is practiced on a variety of scales, down to local subsistence fishing. Although large fishing companies exist, none is big enough to wield market power.[895] In another way, fishing is highly centralized: just 23 countries catch 80 percent of the world's fish.[896] Regional dynamics are also important: Asian and American countries dominate global catch, and

[890] Pitcher and Cheung, "Fisheries: Hope or Despair?"
[891] Elizabeth R DeSombre and J. Samuel Barkin, *Fish* (Oxford: Wiley, 2013), 34.
[892] Ibid., 32.
[893] Ibid., 42, 45; Ian Urbina, "Palau vs. the Poachers," *The New York Times*, February 17, 2016.
[894] Elliott A. Norse et al., "Sustainability of Deep-Sea Fisheries," *Marine Policy* 36, no. 2 (March 2012): 307–20
[895] DeSombre and Barkin, *Fish*, 50.
[896] Ibid., 30.

3/5th of the global catch comes from the Pacific Ocean.[897] China has increased its effort dramatically, and now accounts for 1/6th of global catch.

The geography of extraction is national, regional, and de-centralized, but the geography of consumption is significantly international. Developed countries export and import large quantities of fish, so where a fish is caught, and who catches it, has little impact on who eats it. The United States imports 90 percent of the fish it consumes.[898] Although fisheries are generally over-exploited, uncertainty pervades the calculation of population numbers. The FAO collects global statistics on catches, but they have been criticized for focusing on industrial fishing and ignoring bycatch, illegal fishing, and subsistence fishing.[899] The vast areas around small island developing states are highly targeted and insufficiently monitored, such that an accurate count is impossible.[900] This makes it difficult to provide a detailed characterization of the problem of over-fishing.

Contemporary Ocean Governance Regime

UNCLOS remains the central institution of ocean governance, but it has been modified in two important ways. First, the July 1994 Implementation Agreement amended Part XI of UNCLOS, which deals with seabed mining, to weaken the provisions for distributional equity in an effort to appeal to non-party industrialized countries. UNCLOS entered into force in November 1994 after the sixtieth ratification. Second, the 1995 Straddling Stocks Agreement attempted to fill in where UNCLOS was deficient

[897] Ibid., 28, 37.
[898] Ibid., 35.
[899] Mark McGrath, “Global Fishing Catch Significantly Under-Reported, Says Study,” *BBC News*, January 19, 2016; Daniel Pauly and Dirk Zeller, “Catch Reconstructions Reveal That Global Marine Fisheries Catches Are Higher than Reported and Declining,” *Nature Communications* 7 (January 19, 2016): 10244..
[900] Urbina, “Palau vs. the Poachers”; McGrath, “Global Fishing Catch Significantly Under-Reported, Says Study.”

regarding the management of high seas and migratory fisheries.[901] The Straddling Stocks Agreement mandates a precautionary approach and reaffirms the goals of conservation and optimum utilization, but the Agreement has no formal relationship with Regional Fisheries Management Organizations (RFMOs) and has been ratified by half as many states as UNCLOS.[902] These two agreements modified UNCLOS directly, but the ocean governance regime has advanced in other important ways.

Advances in fisheries management aim to redress the insufficiency of RFMOs, which have grown slightly in number and membership, but remain widely criticized. Efforts have focused on making ships more traceable at sea, and more accountable in port. The 2009 Food and Agricultural Organization Port State Measures Agreement has the explicit goal of blocking the flow of IUU (Illegal, Unreported, Unregulated) fish into markets. It allows port states to deny entry to foreign boats suspected of illegal fishing, and to require detailed documentation and inspection to ensure the legality of the catch. This agreement aspires to overcome existing barriers to effective port state enforcement, including lack of information about IUU vessels, inadequate efforts on the part of ports, and the continued existence of alternative 'ports of convenience.'[903] In terms of at-sea monitoring, in 2000 the International Maritime Organization (IMO) made the use of Automatic Identification Systems mandatory for all ships of a certain size.[904] Because

[901] Jaye Ellis, "The Straddlings Stocks Agreement and the Precautionary Principle as Interpretive Device and Rule of Law," *Ocean Development & International Law* 32, no. 4 (October 2001): 289–311; Syma A. Ebbin, Alf Håkon Hoel, and Are K. Sydnes, eds., *A Sea Change: The Exclusive Economic Zone and Governance Institutions for Living Marine Resources* (Dordrecht, The Netherlands : Norwell, MA: Springer, Sold and distributed in North, Central, and South America by Springer, 2005), 122.
[902] E.J. Molenaar, "Non-Participation in the Fish Stocks Agreement: Status and Reasons," *The International Journal of Marine and Coastal Law* 26, no. 2 (January 1, 2011): 222.
[903] "Port State Performance: Putting Illegal, Unreported and Unregulated Fishing on the Radar" (Pew Charitable Trusts, August 2010).
[904] Md Robards et al., "Conservation Science and Policy Applications of the Marine Vessel Automatic Identification System (AIS)—a Review," *Bulletin of Marine Science* 92, no. 1 (January 1, 2016): 75–103.

this requirement is easy to circumvent, through the use of smaller boats or simply turning off the transponder, NGOs are starting to use satellite monitoring to fill the gaps.[905] Another instrument for high seas governance, Marine Protected Areas (MPAs), are increasing in number and size, and lauded as the "flagship tool" for protecting ecosystems.[906] Despite the lack of an over-arching mandate for MPA creation, scientific observers regularly call for their expansion.[907]

Regime Effectiveness

These additions and augmentations have generally failed to produce an effective ocean governance regime. The basic goals remain sustainable use, equitable access, and economic benefit.[908] The regime has been more reactive than proactive, such that development of practices in any given area precedes their regulation.[909] The management ideal of integration (using complementary regimes to manage multiple uses) has not been achieved, although it still serves as a regime principle.[910] Indeed, parochial interests and existing practices are firmly entrenched, such that regime formation is rarely driven or informed by the structure of collective problems. This section will review some of the

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[905] Brady Dennis, "How Google Is Helping to Crack down on Illegal Fishing — from Space," *The Washington Post*, September 15, 2016; Urbina, "Palau vs. the Poachers."
[906] D. Mouillot et al., "Global Marine Protected Areas Do Not Secure the Evolutionary History of Tropical Corals and Fishes," *Nature Communications* 7 (January 12, 2016): 10359.
[907] Jeff A. Ardron et al., "The Sustainable Use and Conservation of Biodiversity in ABNJ: What Can Be Achieved Using Existing International Agreements?," *Marine Policy* 49 (November 2014): 6; Jane Lubchenco and Kirsten Grorud-Colvert, "Making Waves: The Science and Politics of Ocean Protection," *Science*, October 23, 2015; A. Abelson et al., "Expanding Marine Protected Areas to Include Degraded Coral Reefs," *Conservation Biology*, March 2016; Camille Mellin et al., "Marine Protected Areas Increase Resilience among Coral Reef Communities," ed. David Bellwood, *Ecology Letters* 19, no. 6 (June 2016): 629–37.
[908] The Millennium Development Goals include "environmental sustainability," and the 2030 Sustainable Development Agenda has a goal to "conserve and sustainably use the oceans, seas and marine resources for sustainable development"
[909] H.D. Smith, "The Development and Management of the World Ocean," *Ocean & Coastal Management* 24 (1994): 4, 6.
[910] Ibid., 9.

key failures of the regime, and explain them in relation to the changes in interests, practices, and problems described above.

Marine Pollution

Problems such as plastic detritus, dead zones, ocean warming and acidification cannot be solved by the existing ocean governance regime, because the regime has jurisdiction over the locations where a negative consequence is experienced, but not over the land-based economic activity that is the origin of the problems. These forms of marine pollution cause major disruptions to ocean ecosystems, which are already impacting coastal economies that depend on tourism and subsistence fishing, and which will eventually impact even global fishing in the open ocean. These challenges are "of a magnitude unforeseen in public international law," because their geography extends to the land and atmosphere, and the political geography of UNCLOS does not.[911] Because the chains of cause and consequence involved span the division between the ocean and other planetary domains, the ocean-specific governance cannot solve them.

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[911] Randall Abate, ed., *Climate Change Impacts on Ocean and Coastal Law: U.S. and International Perspectives* (New York: Oxford University Press, 2015), 254.

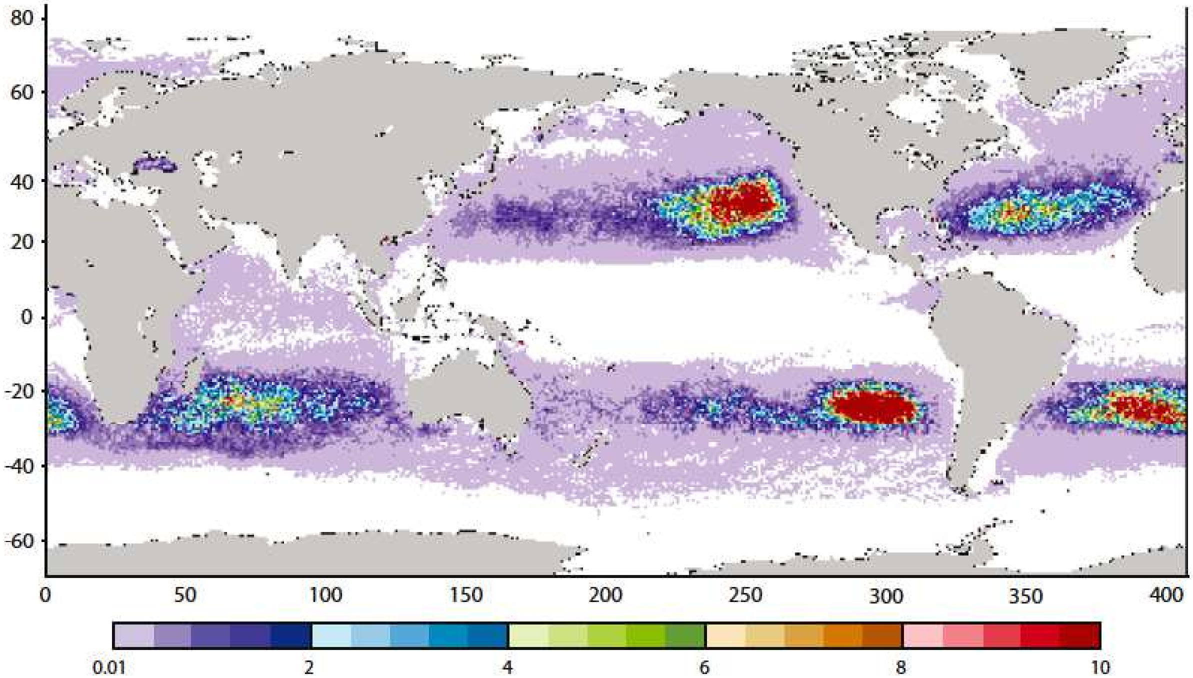

Figure 3: A model simulation of the distribution of marine litter in the ocean after ten years shows plastic converging in the five gyres: the Indian Ocean gyre, the North and South Pacific gyres, and the North and South Atlantic gyres. The simulation, derived from a uniform initial distribution and based on real drifter movements, shows the influence of the five main gyres over time. *Source: IPRC 2008*

Figure 17 - Location of plastic trash gyres, from Kershaw et al. "Plastic Debris in the Ocean." UNEP Yearbook, 2011.

Sea-Level Rise

Sea-level rise is a particularly vexing problem for ocean governance: its causes are atmospheric and international, its effects are planetary in scale, and policy responses so far have been primarily local or national. Sea-level rise does not really harm ocean ecosystems, but it will have major effects on coastal communities and low-lying states. 634 million people live along global coastlines, many in highly urbanized cities with heavy material infrastructures.[912] Although UNCLOS does not have a goal of protecting land-based populations and infrastructure, sea-level rise does affect the ability of the regime to resolve conflicts over maritime jurisdiction zones and territories. The political geography created by UNCLOS – the territorial sea, contiguous zone, Exclusive

[912] Gordon McGranahan, Deborah Balk, and Bridget Anderson, "The Rising Tide: Assessing the Risks of Climate Change and Human Settlements in Low Elevation Coastal Zones," *Environment and Urbanization* 19, no. 1 (April 2007): 17–37.

Economic Zone (EEZ), and continental shelf zone – is constructed on the assumption of a static coastline. The coastal 'baseline' serves as reference point for calculating jurisdictional extent. UNCLOS contains detailed provisions for drawing a baseline, which reference the natural coastline (Articles 5, 7, 14, and 47). The assumption of a static coastline also underlies the very existence of national jurisdiction zones – while an 'island' can generate EEZ and continental shelf claims, a 'rock' cannot (Article 121). The political geography of UNCLOS was built without the expectation of substantial coastal dynamism.[913]

Coastlines have always been dynamic through processes of erosion and deposition, but they are increasingly dynamic in the contemporary era.[914] In some cases, states undertake purposeful dredging to construct islands or expand coastlines for economic or political reasons.[915] But on-going and impending sea-level rise promises to be the main source of coastal dynamism, as rising water levels submerge coastal areas, and as states increase the use of dredging to save coastal infrastructures and population centers. Urban areas are likely to be protected with ever-higher sea walls, but this strategy can actually accelerate erosion, and alters deposition patterns in a way that increases

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913 David D. Caron, "When Law Makes Climate Change Worse: Rethinking the Law of Baselines in Light of a Rising Sea Level," *Ecology Law Quarterly* 17, no. 4 (1990): 621–54; Jonathan Lusthaus, "Shifting Sands: Sea Level Rise, Maritime Boundaries and Inter-State Conflict," *Politics* 30, no. 2 (June 2010): 113–18. Clive Schofield, "Departures from the Coast: Trends in the Application of Territorial Sea Baselines under the Law of the Sea Convention," *The International Journal of Marine and Coastal Law* 27, no. 4 (January 1, 2012): 723–32.

914 Ian Shennan, "Sea-Level Changes and the Threat of Coastal Inundation," *The Geographical Journal* 159, no. 2 (July 1993): 148.

915 Mark Jackson and Veronica della Dora, "'Dreams so Big Only the Sea Can Hold Them': Man-Made Islands as Anxious Spaces, Cultural Icons, and Travelling Visions," *Environment and Planning A* 41, no. 9 (2009): 2086–2104; Edward Wong and Jonathan Ansfield, "To Bolster Its Claims, China Plants Islands in Disputed Waters," *The New York Times*, June 16, 2014.; Joshua Comaroff, "Built on Sand: Singapore and the New State of Risk," *Harvard Design Magazine*, Fall/Winter 2014.

dynamism farther down the coast.[916] In many cases, maintaining existing coastlines will simply be too expensive or too challenging. Low-lying islands in particular are likely to become uninhabitable rocks. Citizens of Kiribati and the Maldives are already assuming they will lose their countries.[917]

UNCLOS assumes that islands will stay islands, rocks will stay rocks, and coastlines will stay put. The treaty lacks legal clarity regarding whether its key jurisdictional categories will shift as the sea level rises. This situation is likely to intensify pre-existing disputes over maritime boundaries, and create new ones.[918] The "vast majority" of overlapping EEZ claims have been resolved by reference to the equidistance principle.[919] When the coastline of one party retreats, the other party is likely to demand that the equidistance line shift to compensate. Low-lying coastal states that experience major coastal retreat, such as Bangladesh, are likely to insist on maintaining their previous baselines. In some cases, sovereign island states may become entirely submerged and uninhabitable, and it is unclear whether this means their maritime jurisdiction zones disappear. If the UNCLOS baseline is allowed to be 'ambulatory' and shift with changes in the coastline, hundreds of bilateral and multilateral agreements will have to be re-negotiated. This option might legitimize China's claims to newly created islands in the South China Sea, an outcome that the United States is likely to strongly reject. The other option, in which political baselines are treated as static even as the

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[916] Richard J.T. Klein et al., "Resilience and Vulnerability: Coastal Dynamics or Dutch Dikes?," *The Geographical Journal* 164, no. 3 (November 1998): 259; Mark T. Gibbs, "Why Is Coastal Retreat so Hard to Implement? Understanding the Political Risk of Coastal Adaptation Pathways," *Ocean & Coastal Management* 130 (October 2016): 109.
[917] Nicholas Schmidle, "Wanted: A New Home for My Country," *The New York Times Magazine*, May 8, 2009; Christopher Pala, "The Island Nation That Bought a Back-Up Property," *The Atlantic*, August 21, 2014.
[918] Lusthaus, "Shifting Sands."
[919] Katherine J. Houghton et al., "Maritime Boundaries in a Rising Sea," *Nature Geoscience* 3, no. 12 (November 30, 2010): 813–16.

coastline changes, would result in interesting situations where maritime zones grow in size, or exist without reference to any coastline at all (in the case of submerged islands). Because UNCLOS was designed without sea-level rise in mind, the treaty text offers no guidance regarding the shifting nature of coastlines. This situation is likely to stoke inter-state conflict.[920]

Fisheries

The ocean governance regime continues to fail at resolving older and more understood problems like the unsustainable use of renewable biotic resources. Despite some success in management of coastal stocks, and a strong legal foundation for conservation of marine ecosystems, defaunation is rapidly increasing.[921] RFMOs are widely understood to have failed at their primary task: maintaining the sustainability of fisheries.[922] Most RFMOs rely on committees to generate estimates of MSY from whatever data is available.[923]Although UNCLOS and the Straddling Stocks Agreement improve upon MSY by requiring the adoption of a precautionary and ecosystem-based approach, RFMOs have "large governance deficits" and have made only "nominal progress" in adherence to these principles.[924]

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[920] Ibid.; Caron, "When Law Makes Climate Change Worse: Rethinking the Law of Baselines in Light of a Rising Sea Level"; Lusthaus, "Shifting Sands."
[921] Kristina M. Gjerde et al., "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction," *Marine Pollution Bulletin* 74, no. 2 (September 30, 2013): 545; D. J. McCauley et al., "Marine Defaunation: Animal Loss in the Global Ocean," *Science* 347, no. 6219 (January 16, 2015): 1255641–1255641.
[922] Sarika Cullis-Suzuki and Daniel Pauly, "Failing the High Seas: A Global Evaluation of Regional Fisheries Management Organizations," *Marine Policy* 34, no. 5 (September 2010): 1036–42; Eric Gilman, Kelvin Passfield, and Katrina Nakamura, "Performance of Regional Fisheries Management Organizations: Ecosystem-Based Governance of Bycatch and Discards," *Fish and Fisheries* 15, no. 2 (June 2014): 327–51.Gjerde et al., "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction."
[923] J. Samuel Barkin and Elizabeth R. DeSombre, *Saving Global Fisheries: Reducing Fishing Capacity to Promote Sustainability* (Cambridge, Massachusetts: The MIT Press, 2013), 25.
[924] Gilman, Passfield, and Nakamura, "Performance of Regional Fisheries Management Organizations."

Each RFMO is an autonomous agreement between a group of members that self-regulate their exploitation of a particular species, or of all commercial species within a particular area.[925] They are open membership, and only create legal obligations over their members. The geographies of membership and jurisdiction in RFMOs are significantly out of step with the geography of exploitation. The fundamental problem is that these regimes are controlled by vested interests seeking to justify existing practices.[926] Advanced technology easily enables long-distance fishing, and can obtain large catches from fish stocks on the brink of collapse.[927] Many states do not become members, but fishers from member states can easily register their ships in non-member states.[928] Little or no effort is made to keep non-member fishers out of an RFMO area. Even when fish stocks are regional, the technological production chain that catches, produces, and sells them is globally interlinked.[929] The problem of RFMO management is put succinctly by Elizabeth DeSombre and Samuel Barkin: "a common pool resource cannot be successfully protected by a sub-group of users."[930]

The RFMO solution set ignores the structure of the over-fishing problem. RFMOs codify a regional political geography, based on an inaccurate agricultural metaphor that considers harvestable resources to be wedded to a plot of territory.[931] Even when particular species have a limited range, fisheries are best understood as a global

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[925] Hance D Smith, Juan Luis Suárez de Vivero, and Tundi Agardy, *Routledge Handbook of Ocean Resources and Management* (Taylor and Francis, 2015), 39.
[926] Gjerde et al., "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction."
[927] Carmel Finley, *All the Fish in the Sea: Maximum Sustainable Yield and the Failure of Fisheries Management* (Chicago; London: University of Chicago Press, 2011), 7.
[928] DeSombre and Barkin, *Fish*, 32.
[929] Gjerde et al., "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction," 544.
[930] DeSombre and Barkin, *Fish*, 9.
[931] Finley, *All the Fish in the Sea*, 7.

system.[932] The resilience of any individual fish stock depends on multiple interdependencies with various scales, such as nutrient flows, seawater composition, predator/prey relationships, disease patterns, and other ecosystem features.[933] Many pelagic species are transient by nature, and therefore extremely difficult to manage within a fixed zonal regime.[934] Indeed, fish are the quintessential fugitive resource, and relatively difficult to locate, track, and count. A governance approach that creates invisible, basically indefensible borders around mobile resources exploited by mobile users, was not likely to succeed. Another form of zonal management – Marine Protected Areas – is also deficient as a conservation strategy because it faces the same challenges.[935] These mismatches between natural, technology, and political geography can be understood as "criminogenic asymmetries" that enable and incentivize IUU fishing.[936]

Ecosystem Based Management

Another weakness of the ocean governance regime relates to ecological knowledge of the material context. The emergence of the Earth system science paradigm prompted the development of the "ecosystem based management" (EBM) approach. Although there is no consensus about the exact principles of EBM, and it lacks a "universal application framework," the basic idea is managing ecosystems as a whole instead of individual species or uses.[937] This approach now pervades the ocean governance regime, and is "broadly accepted" as a principle. The standards for EBM are

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[932] Peter J. Jacques, "Are World Fisheries a Global Panarchy?," *Marine Policy* 53 (March 2015): 165–70.
[933] Ibid.
[934] Game et al., "Pelagic Protected Areas," 362.; Crist, Scowcroft, and Harding, *World Ocean Census*, 112.
[935] Crist, Scowcroft, and Harding, *World Ocean Census*, 147.
[936] Don Liddick, "The Dimensions of a Transnational Crime Problem: The Case of Iuu Fishing," *Trends in Organized Crime* 17, no. 4 (December 2014): 290–312.
[937] Rachel D. Long, Anthony Charles, and Robert L. Stephenson, "Key Principles of Marine Ecosystem-Based Management," *Marine Policy* 57 (July 2015): 53–60.

demanding.[938] It requires managers to account for complex interactions and cumulative impacts at multiple scales, and to factor in the diffuse but significant benefit of 'ecosystem services.'[939] Although the EBM concept is attractive, there exists no clear and feasible method for translating it into specific management practices.[940] The term 'ecosystem' has no consistent legal meaning, and scientists disagree about the appropriate scale for delineation and time horizon for management.[941] Even if ecosystems were easy to differentiate, EBM requires a large quantity of fine-grained scientific knowledge, despite a severely under-sampled ocean. Indeed, marine scientists have only recently made key discoveries, such as crucial role of blue-green bacteria for producing atmospheric oxygen, and the role of whales as "ecosystem engineers" that are responsible for vertical nutrient flows.[942] Additional discoveries are impending, including details about the ecosystem services of the deep-sea.[943] Despite the general consensus that very little of the ocean has been explored and documented, EBM is taken seriously as a management principle. How is this possible?

The EBM approach addresses the lack of ecological knowledge in two ways. The first is using modeling to determine the possible consequences of different situations. These models, because they must function with incomplete information, rely on making assumptions about unknowns. Their attractiveness as a source of quantifiable results is a

[938] Phillip S Levin et al., "Integrated Ecosystem Assessments: Developing the Scientific Basis for Ecosystem-Based Management of the Ocean," *PLoS Biology* 7, no. 1 (January 20, 2009): e1000014.
[939] Ibid.; P Cury et al., "Ecosystem Oceanography for Global Change in Fisheries," *Trends in Ecology & Evolution* 23, no. 6 (June 2008): 338–46; Karen McLeod and Heather Leslie, eds., *Ecosystem-Based Management for the Oceans* (Washington, DC: Island Press, 2009).
[940] Oran R. Young et al., "Solving the Crisis in Ocean Governance: Place-Based Management of Marine Ecosystems," *Environment* 49, no. 4 (May 2007): 22.
[941] Daniel Bodansky, Jutta Brunnée, and Ellen Hey, eds., *The Oxford Handbook of International Environmental Law*, 2. [Nachdr.], 1. publ. in paperback (Oxford: Oxford Univ. Press, 2008), 576, 580.
[942] Bowermaster, *Oceans*; Asha de Vos, "A New Approach to Saving Whales," *Explorers Journal*, October 7, 2014,.
[943] Tony J Pitcher, *Seamounts: Ecology, Fisheries & Conservation* (Oxford; Ames, Iowa: Blackwell Pub., 2007), 57.;Mengerink et al., "A Call for Deep-Ocean Stewardship," 696.

dangerous temptation, and may trade off with problem-focused research.[944] The second is an appeal to the 'precautionary principle' in the event of uncertainty. The strong version of this principle entails shifting the burden of proof from those who want to conserve to those who want to exploit. The principle is not a legal mandate, however, and its main relevance thus far has been as a "framework for discourse about the interpretation and application of legal obligations."[945]

These two means of dealing with the scientific knowledge deficit – modeling and the precautionary approach – are insufficient because they do not overcome key challenges to conceptualizing the ecosystem and achieving holistic management. First, the most relevant characteristics of any given marine ecosystem are how it has changed and how it will respond to change in the future. Historical baselines are useful for "setting responsible goals based on healthy levels of abundance, distribution and biocomplexity in the past."[946] Yet oceanography lacks baseline data for many features of the ocean, especially those dealing with the abundance of particular ecosystems. The hazard is that current species distribution maps will be taken as, and conflated with, habitat suitability maps. There is no known "normal" that can be used to problematize the status quo. Second, there are no non-artificial borders on ocean ecosystems. Every part of the ocean is affected by thermohaline circulation, the interface with the atmosphere, and complex food chains. EBM requires valuation of the provision of ecosystem services, the calculation of which requires considering these types of planetary scale interconnections. Most RFMOs are designed to regulate a single species, and the broadest MPAs are only

[944] Glickson et al., *Oceanography in 2025*, 63.
[945] Ellis, "The Straddlings Stocks Agreement and the Precautionary Principle as Interpretive Device and Rule of Law," 290.
[946] Crist, Scowcroft, and Harding, *World Ocean Census*, 69.

regional.[947] Implementing the ecosystem-based approach regionally requires planetary-scale knowledge, but does not entail planetary-scale control. Even if the problems lie outside regional borders, the solution must occur within them.

Technology

Growth in technological capabilities continues to support access and exploitation instead of surveillance and enforcement. Use practices are supported by strong incentives (profit), while enforcement practices are deterred by cost. A primary example is the complex and overly flexible geography of jurisdiction over maritime shipping. The problem of 'flags of convenience' exists because ships can be registered in any state, regardless of the nationality of the ship owner, captain, and crew, and regardless of where the ship transits or harvests. This system is "based on a legal fiction that a ship is a floating piece of national territory over which the flag State exerts control."[948] Flag states are required to enforce their laws over ships registered there, but owners often choose to register in countries with weak labor and environmental protections and/or negligible enforcement capacity. The result is near free-reign for "pirates, illegal fishers, polluters and various other criminal activities such as arms trafficking."[949] The basic problem is that the political geography remains tied to the territorial state system, while the technological geography of access is complex, fluid, and global.

Technology now penetrates and pervades the planetary ocean in ways that the existing regime is blind to: new practices have emerged, and institutions have not adjusted. The IMO has no provisions to cover drone ships and submersibles; it is not even

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947 Smith, Suárez de Vivero, and Agardy, *Routledge Handbook of Ocean Resources and Management*, 39.
948 Gjerde et al., "Ocean in Peril: Reforming the Management of Global Ocean Living Resources in Areas beyond National Jurisdiction," 544.
949 Denise Russell, *Who Rules the Waves? Piracy, Overfishing and Mining the Oceans* (London; New York; New York: Pluto Press ; Distributed in the United States of America exculsively by Palgrave Macmillan, 2010), 56.

clear whether Autonomous Underwater Vehicles are included in the category of 'ships.'[950] Humans can now deploy machines to reshape coastlines and build islands, yet UNCLOS says nothing about whether these can alter baselines and therefore expand territorial and EEZ claims. This is an increasingly important issue, as China turns reefs into habitable islands in the South China Sea, the trend of artificial island building progresses, and countries like Singapore literally expand their territory through massive dredging.[951] The UNCLOS regime assumes that categories like "ship" and "coastline" are obvious and static, an assumption increasingly challenged by new technology.

Technological capabilities now make possible more effective enforcement, yet surveillance and monitoring technologies are barely deployed by or through the ocean governance regime. RFMOs employ substantially less surveillance technology than they could, allowing illegal fishing to proliferate.[952] Satellite-based receivers have supplemented the IMO's mandatory Automatic Identification System since 2008, but these are still limited by the small number of total receivers.[953] Autonomous Underwater Vehicles represent a "tremendous opportunity" to monitor ocean processes and ocean users, but management institutions are not investing in their deployment.[954] The contemporary ocean governance regime contains no mandates for the use of surveillance technology, and no provisions for the transfer of these technologies.

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[950] Russell B. Wynn et al., "Autonomous Underwater Vehicles (AUVs): Their Past, Present and Future Contributions to the Advancement of Marine Geoscience," *Marine Geology* 352 (June 2014): 466,.

[951] Xavier Furtado, "International Law and the Dispute over the Spratly Islands: Whither UNCLOS?," *Contemporary Southeast Asia* 21, no. 3 (December 1999); Marius Gjetnes, "The Spratlys: Are They Rocks or Islands?," *Ocean Development & International Law* 32, no. 2 (June 2001): 191–204; Jackson and della Dora, "'Dreams so Big Only the Sea Can Hold Them'"; Comaroff, "Built on Sand: Singapore and the New State of Risk."

[952] Gilman, Passfield, and Nakamura, "Performance of Regional Fisheries Management Organizations"; Tabitha Grace Mallory, "China's Global Quest for Resources and Implications for the United States" (2012).

[953] Robards et al., "Conservation Science and Policy Applications of the Marine Vessel Automatic Identification System (AIS)—a Review."

[954] Glickson et al., *Oceanography in 2025*, 57, 148, 155.

Conclusion

Scholars and policymakers recognize many of the flaws in contemporary ocean governance described above. Proposals for regime augmentation tend to focus on incrementally adding new rules to deal with new uses, following the historical pattern of developments in the international law of the sea.[955] More ambitious proposals include the creation of a new centralized authority for management of ocean uses, in recognition of the 'public goods' it provides to humanity as a whole. These institutional blueprints sometimes abolish the EEZ, but the most common element is a "comprehensive ocean authority" with a thicker legal foundation and regional mandates.[956] This purview of this centralized authority would also extend to the high seas and deep ocean, in an effort to regulate high seas fisheries and ensure the provision of ecosystem services.[957] Even those who do not favor a single governance authority still propose forms of centralization, such as Barkin and DeSombre's global fisheries organization.[958] At least one scholar argues that holistic ocean governance creates a "harmony" between political and natural geography, and thereby facilitates "the rationality and effectiveness of ocean governance."[959]

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[955] Ann L Hollick, *U.S. Foreign Policy and the Law of the Sea* (Princeton, N.J.: Princeton University Press, 1981), 9.

[956] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 877–92; Russell, *Who Rules the Waves?*; Natalie C. Ban et al., "Systematic Conservation Planning: A Better Recipe for Managing the High Seas for Biodiversity Conservation and Sustainable Use: Managing the High Seas," *Conservation Letters* 7, no. 1 (January 2014): 41–54.

[957] "Potential Elements of an UNCLOS Implementing Agreement," Protecting Ocean Life on the High Seas (The PEW Environment Group, April 25, 2012); Kristina M. Gjerde, "Challenges to Protecting the Marine Environment beyond National Jurisdiction," *The International Journal of Marine and Coastal Law* 27, no. 4 (January 1, 2012): 839–47; Mengerink et al., "A Call for Deep-Ocean Stewardship."

[958] Barkin and DeSombre, *Saving Global Fisheries*.

[959] Adalberto Vallega, "Ocean Governance in Post-Modern Society: A Geographical Perspective," *Marine Policy* 25 (2001): 411.

These proposals repeat a critical error in recreating a political geography that starts and stops at the coastline. The insights of this chapter suggest that the ocean is not appropriately conceived as a separate and distinct domain for the purposes of management. The public good of an untainted ocean clashes with entrenched private interests in the terrestrial economy, including emissions from burning fossil fuels, agricultural externalities like pesticide and fertilizer runoff, and a consumption society that has deposited 5 trillion pieces of plastic into the ocean.[960] Resolving ocean consequences like acidification, sea-level rise, and chemical/material pollution require regulating their land-based causes. These issues for effective design will be considered at length in the conclusion chapter.

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[960] Oliver Milner, "Full Scale of Plastic in the World's Oceans Revealed for First Time," *The Guardian*, December 10, 2014.

Outer Space: Governance of Orbital Space and Celestial Bodies

After centuries of anticipation, the Space Age began abruptly in the middle of the twentieth century. The movement into space was a major new development in humankind's capabilities, and extremely novel in character. Different types of access to space, for different reasons, emerged over the decades after Sputnik ushered in the Space Age in 1957. A fairly comprehensive regime was put into place before humans had much actual experience with, or use of, orbital space. In political terms, the construction of the outer space regime was near instantaneous. Despite Cold War competition in science and technology, the superpowers converged on a common political framework. Anchored in the Outer Space Treaty (OST), the regime constructed a political geography of open access, with national registration and flagging but no national territories. It outlawed both sovereign appropriation and the basing of weapons of mass destruction in outer space. The broad and skeletal outer space regime has persisted for many decades, but new problems have emerged in the space realm. This chapter answers a basic question: what explains the ineffectiveness of the outer space regime in some areas? I argue that the regime was built too quickly, and then augmented and reformed too slowly, such that it is unable to confront and redress contemporary problems in outer space. The regime has been unable to account for new technological capability and scientific understanding.

This chapter focuses primarily on Earth orbital space (EOS), which includes most human activity in outer space (but excludes inter-planetary probes). Focusing on EOS fits the parameters of a planetary geopolitics approach, because orbital space has a particular and distinctive geography shaped by the gravitational pull of the Earth. This chapter compares the outer space regime with the material context of EOS, especially its geophysical reality and technology-mediated human access. The first section surveys the basic elements of the outer space regime. The second section examines the assumptions about geophysical reality and technological capability made at the time of regime formation, and compares these ideas with what is known about space today. The third section acknowledges the successes and describes the failures of the outer space regime, in both broad outlines and with reference to four specific areas – militarization, space debris, commercialization, and asteroid deflection. The final section considers and evaluates proposals for augmenting the space regime, and draws tentative conclusions about the requirements for a functional and effective regime.

Outer Space Regime

In outer space, as in other non-terrestrial domains, geophysical facts and technological systems condition the types and distribution of practices, the content of interests, and the structure of problems. But because the geophysical features of space and the trajectory of space technology were relatively unknown – they lacked detail or certainty – at the time of negotiation, we should expect to see deficiencies in the outer space regime. When geography is poorly mapped and technology is in its infancy, this situation generates misconceptions about the practices that need to be regulated, the interests being pursued, and the problems that actors are attempting to solve. In this chapter, I argue that the outer space regime is ineffective in particular areas because of a dysfunctional relationship with scientific knowledge accumulation and technological change. This brief section reviews the major parts of the outer space regime, with a focus on the assumptions they embed and reinforce about the material context of activities in EOS. The next section will consider how negotiators, scholars, and diplomats dealt with uncertainty and incomplete information during regime formation, and also survey contemporary knowledge of the outer space environment.

The outer space regime is relatively young and skeletal, compared to other global commons regimes. Most of its elements, including an enduring framework agreement (OST), came into being quickly. The moment of arrival into space was singular, and space actors suddenly confronted the need to create principles, norms, and rules to regulate space activities. Evidence of a collective 'coming to grips' is found in the reliance of international legal scholars on other-domain analogies, and also in the preference of national militaries – the first entrants into space – to defer and delay in answering questions about rights and duties in space.[961] This delay is at least partially explained by a desire be sure of one's interests in space before committing to any formal agreements; discerning interests was "guesswork" full of ambiguities.[962] But of course, norms and expectations about space access came into being as soon as status quo activities were accepted without contestation; international treaty making was not needed for the creation of customary principles of access. This gave a small group of space-capable actors (initially a group of two) substantial leverage in interpreting their obligations to each other and the international community more generally.[963] The principles for governing outer space were therefore mostly built as customary international law (starting in 1957), and only subsequently and intermittently codified in international law and treaties (starting in 1967).

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[961] Delbert R. Terrill, *The Air Force Role in Developing International Outer Space Law* (Maxwell Air Force Base, Alabama: Air University Press, 1999).
[962] Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age*, Cass Series--Strategy and History (London ; Portland, OR: Frank Cass, 2002), 114.; Glenn H. Reynolds and Robert P. Merges, *Outer Space: Problems of Law and Policy*, 2. ed (Boulder, Colo.: Westview Pr, 1998), 6.
[963] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 880.

Because of concerns about superpower conflict spilling into and escalating in outer space, the main goal of early diplomatic initiatives regarding space was "to confine the use of outer space to peaceful purposes."[964] The space powers were motivated by both individual and collective security; they wanted to avoid great power war in space, and also maintain safe access to orbit and beyond. By the early 1960s, the United States and Soviet Union began to sense a shared interest in reserving space for peaceful purposes, including civilian programs, military support functions, and scientific observation.[965] The 1962 Starfish Prime nuclear test demonstrated the possible magnitude of indiscriminate damage for both superpowers.[966] The 1963 Limited Test Ban Treaty (LTBT) outlawed nuclear explosions in space, and a 1963 U.N. General Assembly Resolution called on states to refrain from putting weapons of mass destruction in orbit or on celestial bodies. In view of the "common interest" in peaceful uses of outer space, the 1967 Outer Space Treaty formalized the prohibition on WMD, and also outlawed territorial claims. The negotiation and entry into force of OST marks the beginning of a concentrated period of regime formation.

The outer space regime is primarily composed of four treaties or conventions, all negotiated in the 1960s and 1970s: the Outer Space Treaty (1967),[967] Agreement on Rescue and Return (1968),[968] Registration Convention (1976),[969] and Liability

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[964] Philip C. Jessup and Howard J. Taubenfeld, *Controls for Outer Space and the Antarctic Analogy* (New York: Columbia University Press, 1959). 5

[965] James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (Stanford, Calif: Stanford Security Studies, 2008), 115.

[966] Jeff Dougherty, "War in Space: Anti-Satellite Weapons," *Modern War*, June 2013, 64.

[967] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies

[968] Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space

[969] Convention on the Registration of Objects Launched into Outer Space

Convention (1972).[970] The Outer Space Treaty (OST) can be understood as both the core of and framework for the outer space regime. As the core, it is a "Treaty on Principles" that outlines the central commitments of signatories to non-appropriation, peaceful use, and shared benefits. As a framework, its somewhat-vague categories and concepts have been fleshed out by follow-on agreements and resolutions, but the OST itself has never been challenged, amended, or replaced; it "enjoys the broadest subscription and the highest regard."[971] Its durability does not necessarily indicate effectiveness, however, as there are many possible reasons OST has not been altered. The appetite for regime building was lost in the 1980s, primarily because renewed Cold War tension spilled over into disagreements at the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS).

The regime is a two-layer regulatory system, where international agreements bind states, which must then enforce treaty provisions on their domestic actors. According to Article 6 of OST, state members are responsible for "authorization and continuing supervision" over non-governmental actors. At the time of its negotiation, there were no independently capable private and/or commercial non-state space actors.

Collectively, these agreements constructed space as an international commons "based on the principles of equal access and freedom of exploitation and use by all states."[972] Outer space could have been declared *res nullius* – making it a nascent part of the territorial state system – but instead it was declared *res communis*, an international

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[970] Convention on International Liability for Damage Caused by Space Objects
[971] Reynolds and Merges, *Outer Space*, 62.
[972] Daniel Bodansky, Jutta Brunnée, and Ellen Hey, eds., *The Oxford Handbook of International Environmental Law*, (Oxford: Oxford Univ. Press, 2008), 333.

arena that could be used by all but appropriated by none.[973] The OST describes outer space as the "province of all mankind," which is not defined precisely, but generally understood as a weaker commitment than the "common heritage of mankind" designation given to the deep seabed. The decision to declare outer space the common 'province,' used only for peaceful purposes and without state appropriation, extended a political geography of the 'commons' already developed in the context of the high seas. This principle precludes sovereign territorial claims, but "leaves open the possibility of resource use."[974] Users are obliged to "take into consideration the interests of others" when using space.[975]

An open access *res communis* regime was not the only option for creating political geography in space. The alternative scheme of partition was considered and rejected, because of the basic geophysical features of orbital space. The first and default choice of the territorial state system is typically the extension of the political geography of terra firma, by declaring newly discovered *res nullius* and incorporating it into state territory. The basic obstacle to doing so in EOS was that partition would make orbital space un-usable, because satellites by nature pass over large swaths of the Earth's surface. This also significantly explains the durability of the core free passage provision, which is necessary to make space usable by satellites. In other words, a fundamental feature of geophysical reality, interacting with technological systems, conditioned the basic structure of the regime. In this, the interests of current and future space actors were abundantly clear. However, there was much that the architects of the outer space regime

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[973] M. J. Peterson, *International Regimes for the Final Frontier*, SUNY Series in Global Politics (Albany: State University of New York Press, 2005), 43.
[974] Bodansky, Brunnée, and Hey, *The Oxford Handbook of International Environmental Law*, 334.
[975] Ibid., 33.

did not know or could not foresee about the material context of EOS, and this lack of complete information would impact the regime's future effectiveness in the decades to come. Notably, the Treaty does not define the realm of outer space, and only makes a single reference to it being distinct from air space.

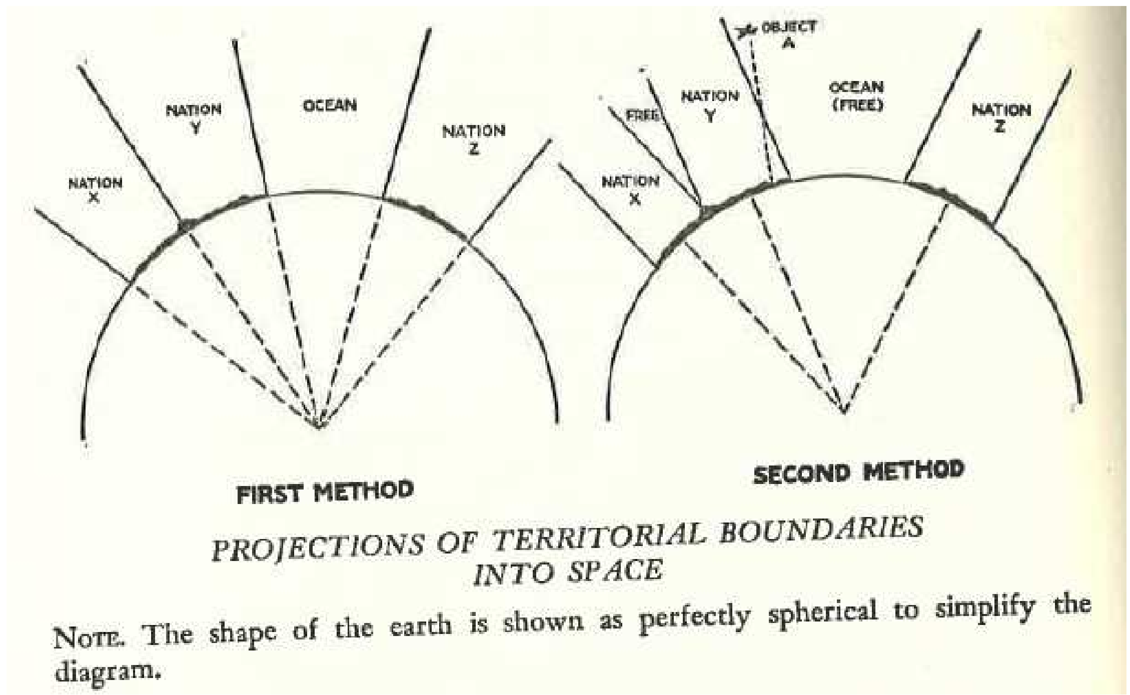

Figure 18 - Consideration of partition schemes, From Jessup, Philip C., and Howard J. Taubenfeld. Controls for Outer Space and the Antarctic Analogy. New York: Columbia University Press, 1959.

Material Context

At the time negotiations over OST began, "most governments had little conception of space or space activity."[976] M.J. Peterson describes how actors first had to establish a "locational classification" for outer space in order to define the situation precisely. From this classification, actors could begin to glean their interests and relative identities, and only then pursue the creation of particular institutions to manage outer space. This idealized two-step process is reflected in the division of COPUOS into a Scientific and Technical subcommittee and a Legal subcommittee. Until the mid-1970s, COPUOS was the "single most important source of international law relating to space activities."[977] The Scientific and Technical subcommittee was charged with developing shared knowledge about space and the potentials of space activity, while the Legal subcommittee drafted multilateral agreements. But the Legal subcommittee got ahead of its counterpart. Peterson argues that lawyers – highly trained in analogical reasoning – had the largest influence on early regime formation out of COPUOS.[978] The result was a reliance on "direct transfers of idea from similar types of earthly activity," a process which Peterson describes but does not problematize.[979] By the time COPUOS activity slowed down in the late 1970s and 1980s, the proportion of technical experts had decreased in favor of diplomatic generalists. The influence of international lawyers and diplomats, as opposed to space scientists and engineers, may partially explain why the regime was based on a fuzzy and imprecise understandings of the EOS material context. This section reviews two different accounts of the process of "locational classification" in

[976] Peterson, *International Regimes for the Final Frontier*, 67.
[977] Reynolds and Merges, *Outer Space*, 47.
[978] Peterson, *International Regimes for the Final Frontier*, 13.
[979] Ibid., 7.

outer space during early regime formation, and then surveys contemporary scientific descriptions of outer space.

Many scholars like Peterson have analyzed the role of other-domain analogies for the formation of the outer space regime.[980] These are a kind of materialist argument, because they detail how actors came to understand the geography of the place where they were interacting. But these existing treatments, and especially the extensive reviews from Peterson, have three disadvantages: First, Peterson describes the switch from one analogy to another as a result of both superior political 'fit' with the purposes of dominant actors, and better 'fit' with the material realities of outer space. But she does not differentiate the character of these causes, and therefore overlooks the way that processes of scientific knowledge accumulation progressively reinforce the appropriateness of some analogies while undermining others. Indeed, Peterson repeatedly suggests that "purpose" and "perceived interests" explain the adoption of particular spatial understandings of the domain.[981] Second, she provides no way to evaluate representations except from a particular perspective – do they serve the interests of particular actors? Third, Peterson's approach fails to translate such insights into prescriptions for better policy-making in response to further problems. Will any of these analogies help us confront problems like space debris? Peterson does not answer this question. Although her work on the outer space regime is detailed and insightful, I will argue that there are advantages to taking a more strongly materialist approach.

[980] M.J. Peterson, "The Use of Analogies in Developing Outer Space Law," *International Organization* 51, no. 2 (Spring 1997): 245–74; Peterson, *International Regimes for the Final Frontier*.; Sven Grahn, "Why We Had Better Drop Analogies When Discussing the Role of Humans in Space," in *Humans in Outer Space — Interdisciplinary Odysseys*, ed. Luca Codignola and Kai-Uwe Schrogl, vol. 1, Studies in Space Policy (Vienna: Springer Vienna, 2009); Howard E. McCurdy, "Reaching for Higher Altitudes: Mountaineering Analogies and the Commercialization of Outer Space," *Astropolitics* 12, no. 2–3 (September 2, 2014): 132–47.

[981] Peterson, "The Use of Analogies in Developing Outer Space Law," 250, 269.

Another approach to explaining "locational classification" comes from the constructivist school of International Relations, which focuses on the social construction of ideas and concepts. In his 2016 article "Unearthing global natures: outer space and scalar politics," Jason Beery adopts a "production of nature approach" to understanding how outer space came to be understood as a "global commons." This approach understands the global scale of outer space "as socially produced, as discursively deployed, and as a political tool." Beery rejects the existence of a "fixed, pre-given, and separate" natural world, and insists that scientific "framings" of nature are inherently political.[982] He argues that the prevailing construction of outer space as a 'global commons,' solidified in the OST, served the interests of dominant actors by reinforcing technological, economic, and political inequality. Although, like Peterson, Beery actually relies on the features of material reality in his explanation, these disappear in his concluding description of the construction of outer space. He argues that outer space is defined by non-appropriation, free access, and collective benefit. But these are political features of the regime, constructed on a foundation of understandings about the geophysical features of the space environment. In other words, Beery believes that outer space is defined by the political geography of the 'global commons,' instead of the planetary geography of a non-terrestrial domain of the Earth. Although Beery's approach assumes that 'nature' is socially constructed, he relies on features of the actual material context to explain why territorial partition and spatial demarcation of outer space were not pursued.

[982] Jason Beery, "Unearthing Global Natures: Outer Space and Scalar Politics," *Political Geography* 55 (November 2016): 94.

Both of these sets of arguments about the outer space domain are inferior versions of a more strongly materialist approach, one premised on the existence of an objective material world that is progressively characterized by scientists. Peterson alludes to this premise, while Beery flatly rejects it. Peterson argues against a purely rationalist explanation of regime formation, and analyzes the influence of analogies on interest formation. She explains that both lawyers and scientists contributed to the "standards" for evaluating representations of outer space, but she greatly underplays the latter group. While international lawyers were orienting by reaching for analogies to frame their

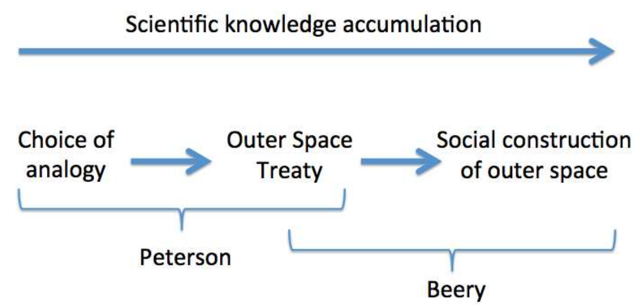

Figure 19 - Established views on outer space regime

space law proposals, scientists were orienting by collecting, synthesizing, and interpreting data about the domain itself. The assumption that an objective, geophysical outer space exists is evident when Peterson surveys the pitfalls of analogic reasoning – she says that the "existence" of a domain feature may be over-looked, or inaccurately presumed, because of a reliance on an analogy.[983] But ultimately Peterson, like Beery, concludes that the purposes and interests of dominant space actors determined which representation of the space environment was incorporated within and reproduced by the outer space regime. Their arguments imply that political actors can build the regime that suits their interests, regardless of the 'raw material' of the domain to be managed. A central argument of this chapter is that interest formation is inherently corrupted or skewed without direct reference to scientific knowledge of the material context.

[983] Peterson, "The Use of Analogies in Developing Outer Space Law," 249.

The influence of geophysical features of outer space is generally under-appreciated in the literature analyzing the history of access to space.[984] A strong materialist approach highlights the role of geography, geophysics, and technology in shaping the practices, interests, and problems that motivate the formation and operation of a regime. This approach has two major differences with the approaches of Peterson and Beery. First, it suggests that analogies are ill suited to drive regime formation, because they inevitably create misidentifications and mischaracterizations of interests and problems. Second, it focuses on a source of image construction outside the minds and practices of social actors – the actual material world, mapped and characterized by a diverse scientific community following a shared scientific method. This geopolitical approach posits a crucial distinction between international actors, a constructed global commons regime, and an actual material planetary-scale space. The actors and their constructed regime are not all that exists in EOS – the place itself conditions, constrains, and influences the actors' interests, practices, and power and therefore shapes the regime, and whether it effectively realizes the interests that motivate its formation.

Taking seriously the role of an objective material context – one that exists independently of human perception – has several advantages for understanding the construction and operation of the outer space regime. First – in explaining the evolving image of outer space, this approach separates political and material explanations. The distinction provides the analyst with a better idea about the durability of trends in space access. For example, fluctuating terrestrial mineral prices offer a contingent explanation for the pursuit of lunar or asteroidal mining. In contrast, the existence or absence of

[984] R. D. Launius, "Writing the History of Space's Extreme Environment," *Environmental History* 15, no. 3 (July 1, 2010): 526–32.

particular minerals on other planets, moons, and asteroids provides a durable explanation for whether celestial mining is pursued. While this example is particularly simple, durable and predictable material trends also exist regarding launch requirements, orbital paths, human physiological limitations, remote sensing and communication physics, and other features of space activity. The key point, as Martin France et al. succinctly states, is that "some constraints…are not subject to negotiation."[985] Second – the geopolitical approach helps explain the formation of particular interests and purposes regarding space; what we want is shaped in part by what we can do, and what we can do is significantly determined by the interaction between current technology and geophysical realities. Third – the material approach easily engages with Realism, which dominates the approach of many space practitioners, scholars, and theorists.[986] While many Realists focus on outer space as a realm of inter-state competition, realist theory takes seriously claims about technological innovation, terrain, and resource distribution. In particular, Realist geopolitics appreciates the existence of 'spatial extension' and location-based resources. But Realism has other flaws that make a distinct materialist geopolitical approach necessary. Realists tend to import strategic principles from terrestrial politics, and most see competition in space as inevitable.[987] Finally – because the materialist approach employs a scientific standard for evaluating representations of outer space, it is more suited to guiding effective national and international action in space. Geopolitics suggests that interests are best pursued, and problems best avoided, when scientific practitioners

[985] Martin E.B. France et al., "Real Constraints on Spacepower," in *Toward a Theory of Spacepower* (National Defense University: Institute for National Strategic Studies, 2011), 43–44.
[986] Dolman, *Astropolitik*.; Robert L. Pfaltzgraff, "International Relations Theory and Spacepower," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011).
[987] Pfaltzgraff, "International Relations Theory and Spacepower," 30, 34.

have thoroughly investigated the domain and objects of the outer space regime. Thorough investigation often results in consensus formation about the consequences of various practices in space, but it can also reveal areas of persistent uncertainty. Either set of information is useful for the design of effective regimes.

Domain analogies

The persistent use of analogies for describing, understanding, and ordering the outer space domain represents a collective 'coming to grips' with the geography of this new domain of human activity. Analogies make familiar the otherwise unfamiliar, and are therefore a source of guidance for confronting new situations. Analogies to the outer space domain are widely employed in the speeches of policymakers, arguments of diplomats, reports of analysts, and studies of scholars. Their prevalence implies a lack of confidence in descriptions of the outer space environment. This could in part be accounted for by the fact that few who discuss space will ever actually go there, but the same can be said for the domains that have been the source of such analogies: the ocean (high seas and deep seabed), air space, and Antarctica. Analogies with other geophysical domains serve as a vehicle for importing pre-existing legal principles, norms, and rules to help guide the creation of an outer space regime. The assumption has been that domains most similar to outer space – geographically, technologically, and politically – would provide the most useful legal concepts for managing outer space. The materialist geopolitical approach suggests that this is an inherently flawed strategy, because the material context of the ocean, air, and frozen continent are *not* the same as the orbital space environment. This section will review why such analogies were appealing, and what they captured and obscured about the space environment. Analogies are chosen for their fit with material surface features, as well as their fit with the interests of powerful actors.

The analogy that most dominated the early and middle periods of space activity compared outer space to the ocean.[988] There are several features of this analogy, which were emphasized at different times. The version with the most uptake in the international community is that space is like the high seas, and should therefore be treated as an open access area that can be used by everyone, but not appropriated by anyone. On the high seas, states are responsible for enforcing regulations on their own nationals. The view that outer space was like high seas helped define its political-geographical border with airspace, which could be understood as similar to the territorial seas.[989] Some of the most transferrable precedent came from the comparison of obligations associated with ships and crews, such as those regarding rescue, piracy, navigational aids, liability, and registration.[990]

The idea that outer space is like the high seas had intuitive appeal, because both are vast and fluid, and contain areas of solid material. It was also readily available as a result of the on-going negotiations over the law of the sea, which reinforced traditional customs regarding high seas access. Diverse groups still regularly employ the ocean/space analogy. Realists draw on Alfred Thayer Mahan's arguments about sea power for insights about spacepower.[991] Even oceanographers reinforce the comparison, in terms of the requirements of research and exploration: "complex technology,

[988] William E Burrows, *This New Ocean: The Story of the First Space Age* (Modern Library, 2010).
[989] Peterson, "The Use of Analogies in Developing Outer Space Law," 252.
[990] Jessup and Taubenfeld, *Controls for Outer Space and the Antarctic Analogy*, 212.
[991] Jon Sumida, "Old Thoughts, New Problems: Mahan and the Consideration of Seapower," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 10.; Colonel John E. Shaw, "Guarding the High Ocean: Towards a New National Security Space Strategy Through an Analysis of US Maritime Strategy," *Air & Space Power Journal*, Spring 2009.

innovative ways of getting to and from extreme environments, and, once there, the courage to investigate."[992] The high seas analogy also implied a parallel between islands in the ocean, and 'islands in space.'[993] While islands in the ocean were historically territorialized, international lawyers and diplomats did not want celestial bodies to be characterized as *res nullius* and be subject to state appropriation. Neither side of the 'space race' knew who would get to such places first, so both preferred a principle of non-appropriation. The argument that moons and asteroids should not be understood as islands required an analogy shift.

The analogy between outer space and Antarctica became salient towards the end of negotiations, and "supplied solutions to a number of practical problems."[994] In both Antarctica and space, diplomats were confronted with the question: is this area *res nullius*, or is it something else? The Antarctica Treaty System (ATS) came into being in 1959, and was understood as a test for international cooperative forms that might be applied to space.[995] Some observers elevate the role of the ATS to the analogical "base model" for the outer space regime.[996] It provided a rationale for the setting aside of territorial claims in favor of designating a commons, the retention of control over national objects and people, and continued space activity without the risks of Cold War rivalry.[997] The ATS and OST also both enshrine the right of peaceful scientific research.

The analogy between airspace and outer space is supported by their shared ascendant position and the notion that vehicles in either are 'flying.' The term 'aerospace'

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992 Darlene Trew Crist, Gail Scowcroft, and James M. Harding, *World Ocean Census: A Global Survey of Marine Life* (Richmond Hill, Ont. ; Buffalo, New York: Firefly Books, 2009), 77.
993 Dandridge M. Cole and Donald W. Cox, *Islands in Space: The Challenge of the Planetoids* (Philadelphia, PA: Chilton Company, 1964), 7–8.
994 Peterson, "The Use of Analogies in Developing Outer Space Law," 258.
995 Jessup and Taubenfeld, *Controls for Outer Space and the Antarctic Analogy*, 6.
996 Dolman, *Astropolitik*, 123.
997 Peterson, "The Use of Analogies in Developing Outer Space Law," 257–59.

reflects the belief that space is a continuation of airspace, and some legal scholars at the beginning of the Space Age proposed that the legal regime for airspace was an important precedent for outer space. Problems associated with injury, damage, and loss from space vehicles have been described as "identically the same…in international air law."[998] This suggests a similarity in terms of rules about nationality, liability, and safety. But the airspace analogy fell out of favor quickly, and virtually no one forwarded it after 1961. Peterson argues that the strongest explanation – a materialist explanation – is the "poorer fit with what was known about space," particularly the basic nature of orbital mechanics.[999] The air analogy implied that outer space should be divided into national segments treated as sovereign territories, but "lawyers and governments alike had trouble conceiving how a country might claim sovereignty over a vacuum whose location was constantly shifting."[1000] Of course, it was not the vacuum itself with a shifting location. Objects in any orbital trajectory, even those that appear stationary relatively to a point on Earth, are constantly moving through different points in space. The airspace analogy was rejected for the same basic reason partitioning was abandoned: sovereign territory makes little sense in the orbital space environment.

None of these analogies is useful or appropriate for fully defining the political situation in outer space, because each source domain lacks the basic structural features of the target domain. Most obviously, the space environment is practically and perhaps theoretically infinite, whereas the ocean, atmosphere, and land have "knowable finite

[998] Irvin L. White, *Decision-Making for Space: Law and Politics in Air, Sea, and Outer Space* (Purdue University Studies, 1970).
[999] Peterson, "The Use of Analogies in Developing Outer Space Law," 268.
[1000] Ibid., 252.

bounds."[1001] In this sense, each of the three analogies commits a fundamental category error. It might be argued that analogies, by definition, contain only partial identity with or similarity to the target domain, and that what they do capture about reality justifies their use. The problem is that analogies are used as an expedient to understand situations without much information, so users are poorly suited to identify which parts of a given analogy are revealing, and which are concealing. Indeed, when analogies are first employed, the user assumes that "the target domain is similar in all respects to the source domain."[1002] This entails a high probability of misreading, misperception, and mistakes in problem definition and interest formation. What is needed is a kind of 'geography criticism,' which evaluates the extent to which a given analogy includes or omits accurate information about the material context.[1003] Ultimately, the whole enterprise of choosing between ocean, air, and Antarctic analogies is flawed, because each analogy obscures fundamental material features of outer space. There are three major features of the EOS environment that these analogies overlook or distort.

First – unlike the ocean and Antarctica, outer space contains no ecology – no ecosystems, no endemic life whatsoever. The presence or absence of ecosystems matters for governance, because ecosystems contain properties of self-sustainability and renewal that can moderate and regulate the impacts of human activities. Animals reproduce, carbon can be sequestered, ice refreezes, toxins disperse, and even continental crust is renewed. Outer space does not contain ecological sources of renewal and stabilization; it

[1001] Pfaltzgraff, "International Relations Theory and Spacepower," 28.
[1002] Peterson, "The Use of Analogies in Developing Outer Space Law," 249.
[1003] Daniel Deudney and Elizabeth Mendenhall, "New Earths: Assessing Planetary Geographic Constructs," in *The Politics of Globality since 1945: Assembling the Planet*, ed. Rens van Munster and Casper Sylvest, New International Relations (London New York, NY: Routledge, 2016).

is fragile and has limited capacity to repair itself.[1004] Lack of ecosystems also means that outer space does not contain harvestable, renewable, resources that can go extinct. The features of these types of resources give a particular meaning to 'sustainable use.' Indeed, almost no material resources – finite or renewable – have been harvested from space.[1005] The space resources currently used are spatial extension resources, like orbital paths and ballistic missile trajectories. Even these are unlike sea and air lanes, in that their traversal does not entail negative externalities for ecosystems. This creates significantly different conditions for achieving sustainable access and use. It also represents a unique context for treaty negotiations – in the ocean, valuable and readily accessible resources were at stake, whereas in outer space, resources were speculative or difficult to access, especially in the near term.[1006]

Second – unlike the ocean and atmosphere, outer space is not a fluid domain in the sense of having 'flows' of liquid or gaseous particles.[1007] These winds and currents – driven by density and pressure gradients, among other material properties – shape the patterns of ecosystem productivity, and also distribute external inputs like air and water pollution. In contrast, uncontrolled and 'cast off' objects in orbital space tend to spread out evenly in a shell around the Earth. Fluidity is also absent on the lower edges of orbital space; the border of EOS is uncertain, but it is not understood to be undergoing constant fluctuation. The only exception to this is when solar flares heat the Earth's outer atmosphere, causing it to temporarily expand. But this dynamism is miniscule and

[1004] Moltz, *The Politics of Space Security*, 6.
[1005] The exception is the use of solar power as an energy source for orbiting satellites.
[1006] Ann L Hollick, *U.S. Foreign Policy and the Law of the Sea* (Princeton, N.J.: Princeton University Press, 1981), 14.
[1007] The phenomenon of 'solar wind' described in the next section is not comparable, despite its name. Solar winds do not constitute (or fill) the outer space environment in the ways that air and water molecules constitute the atmosphere and ocean. Solar wind flows outward from the sun, instead of circulating, and it is made of plasma, and therefore not a medium that can be inhabited or traversed.

momentary compared to other domains. The borders of the atmosphere and ocean are shaped by molecular movements and exchanges in and between each domain, and are constantly in flux due to erosion, deposition, runoff, industrial emissions, and sea surface exchange. In addition to the obvious coastal border between land and sea, the problems of air and water pollution and ocean acidification represent a porous natural border. Problems that originate in one domain and have negative consequences in another demonstrate that, for the purposes of effective collective management, the borders between land/air/sea are largely artificial. In contrast, terrestrial, aerial, and maritime activities barely affect orbital space, with the exception of the thousands of machines that humans intentionally send there, which are closely tracked and monitored. These global-scale technological systems create their own material patterns and processes in non-terrestrial domains.

Third – space technology, and the way it facilitates access and activity in space, is fundamentally different from aerial and maritime technologies. Take the example of vehicles. 'Ships' are designed for operation in all three non-terrestrial domains, but their common name is more analogy than equivalence.[1008] Aircraft and boats – commercial, military, recreational – are durable and reusable. In the case of watercraft, the technology may be very basic, and is highly diffused across the planet. Although aircraft are more complicated and expensive, they are usually flown for several decades before being decommissioned. In contrast, space access technology is extremely expensive, complex, and fragile. Many space vehicles, such as rockets, are 'single use,' and even reusable vehicles require significant repair and refurbishment between trips. Although this is not

[1008] The first three entries for 'ship' in the New Oxford American Dictionary refer to racing boats, sailing vessels, and transportation by the sea. The fourth entry is for a 'spaceship' and the last for an aircraft, with the qualification that this last meaning is common only in North America.

necessarily a permanent condition of space vehicle technology, the difference in operational environments increases the barriers and obstacles to robust and reusable spacecraft. Space vehicles also need different materials and manufacturing; they can be weaker in some ways, for example because they do not encounter terrestrial weather, but they need to be stronger in others, such as shielding from radiation. These technological differences are significant, because they result in different numbers, distributions, and types of users. The more distinctive and expensive a technology, the fewer actors have access to it. These patterns create particular conditions for regime formation where space users either have vastly more or less leverage, depending on the topic at hand. Features of technology also impact the prospects for particular regulatory strategies. For example, the question of how and whether to 'flag' a space vehicle via permanent markings was an important part of the negotiations over registration.[1009] Flagging a boat and painting an aircraft proved far easier than marking a vehicle that travels through the atmosphere at extremely high speeds and temperatures. In the early 1970s, the COPUOS Scientific and Technical Subcommittee concluded "there was no feasible way to put marks capable of surviving the high heat of reentry on space objects and their components."[1010]

[1009] Peterson, *International Regimes for the Final Frontier*, 88.
[1010] Ibid., 98.

Table 2 - Analogies for outer space

Analogy	Version	Captures about space MC	Misses about space MC	Presence in regime
Ocean	High seas	Vast, fluid; Solid islands; Obstacles to deep access; Coastal area (airspace)	Infinite; Effective distance (speed of vehicles); Delicate and expensive technology; Security issues; Space ports (leave, don't arrive)	National registration; International commons; CIL principles instead of positive rules; Rescue obligations
Ocean/Land	Seabed	Vast potential mineral wealth; Obstacles to access	No ecological context; Separate mineral caches	Moon Treaty (CHM)
Land	Antarctica	Harsh environment; unknown resource extent; Distance; Uninhabited except few settlements	Mostly unable to partition; Requirement of advanced technology	International commons; National control over humans, vehicles, stations; functional coordination comes first; scientific cooperation
Atmosphere	Airspace	Ascendance and 'flying'; Vehicle safety issues; Vehicle registration needs	Orbital mechanics; Obstacles to partition	Liability rules

Because the political geography of outer space was constructed from a series of air, ocean, and Antarctic legal precedents, there is a prima facie reason to expect a mismatch between the political and material geography of outer space.[1011] In short, analogies mislead. Because non-terrestrial domains are fundamentally different from one other, it is not likely that regime features designed to govern one domain will be effective when applied to another. The distinctive features of the ocean, atmosphere, and outer space entail different constraints, opportunities, and motivations for regime building.[1012] This geographical mismatch, combined with a heavy reliance on analogies, results in corrupted, distorted, and myopic conceptions of possibilities for activities and thus of interests and preferences in outer space. Spatial disorientation makes for difficult steering. Functional regimes are designed to achieve specific social, political, and economic purposes in a domain. But because they 'function' by regulating technological

[1011] Dolman, *Astropolitik*, 117.
[1012] Susan J Buck, *The Global Commons an Introduction* (Washington, D.C.: Island Press, 1998), 10.

activities in the material space environment, a clear and precise representation of the domain is vital to the creation of an effective political geography. A central argument of this chapter is that the presence or absence of reliable and detailed information about particular features of the outer space environment has a strong influence on both regime design and effectiveness. When information is lacking and understandings are incomplete, interests are poorly formed and problems weakly defined. The standard by which a representation of outer space should be evaluated is not its satisfaction of the interests of states and other actors, because those interests cannot be taken as pre-defined and given.

An example of scientific knowledge the regime builders did have is information about the vacuum of space and orbital dynamics. This geophysical reality constrained the options for regime design. Whether or not a domain becomes a 'global commons' or is carved into sovereign territorial states is often understood to as a political question. It has been argued that the superpowers both benefitted from and were cheated by the Outer Space Treaty's declaration of space as a global commons.[1013] Interests and power cannot fully explain why space was declared a commons instead of carved into territorial parcels. An 'unknown' domain becomes 'known' not simply through the construction of a political geography, but through increasing scientific knowledge about the contours of the space itself, and the capabilities and requirements of technological access. The processes of scientific knowledge production and technological advancement have continued for decades after the construction of the regime; our abilities in and understandings of the outer space environment are significantly advanced relative to the 1960s.

[1013] Dolman, *Astropolitik*; Beery, "Unearthing Global Natures."

The next two sections review the state of contemporary scientific knowledge and technological capability in the outer space environment. While these topics are addressed separately, this distinction is more heuristic than real. The advancement of science and technology are closely related in general, but this connection is especially pronounced in space, and clearly demonstrated by the early case of the telescope. The innovation and progressive development of telescopes revolutionized our understanding of the Earth and the universe, by providing access to new information and stimulating the emergence of new ideas about space. First, outward-pointing telescopes confirmed nascent theories about the heliocentric solar system, the movement of the Earth, and the nature of the stars. As telescopes got bigger and better, astronomers began to identify asteroids and other celestial phenomena. Then, telescopes were placed in space, beyond the obscuring filter of the atmosphere. In addition to learning about more distant space objects, and with more detail, telescopes were pointed inward at the Earth to gather information about this planet. This example powerfully demonstrates how both scientific study and technological advance contribute to the refinement of our representations of outer space as a place distinct from domains within the atmospheric envelope.

Geography

The geography of outer space is frequently misperceived. It appears to be a distinctive and separate place that is empty, abstract, and smooth. But in reality, outer space, and especially Earth orbital space (EOS), is highly textured. EOS is the part of space where the Earth's gravitational attraction is overwhelmingly dominant. Although EOS is vastly larger than the atmosphere in total volume, the increase in speed made possible because of lack of friction means that distance is actually compressed. Outer space travel represents a decrease in "effective distance": even very long distances can be traversed quickly when traveling at very high speeds.[1014] Because of gravity and the increase in speed, EOS should be understood as the outer shell of the planet, as opposed to the anteroom of an infinite universe.

The environment of outer space is overwhelmingly inhospitable to human life, and creates a set of obstacles for the operation and maintenance of human technology. Outer space is difficult to get to, be in, and return from. Because it is a vacuum, terrestrial organisms cannot live in outer space without the assistance of advanced technology. Space-based objects experience enormous variation in temperature, depending on their location relative to the sun. Outside of the protective filter of the atmosphere, radiation abounds. The 'solar wind' entails a continuous and high-velocity flow of charged particles from the sun, with occasional eruptions of intense high-energy radiation called 'solar flares.' An additional source of radiation is 'cosmic rays' from outside the solar system. These high-energy particles travel an appreciable fraction of the speed of light, and can do massive damage to biological tissue. Such radiation flows through orbital space, but it is also concentrated there. The Van Allen belts are dense layers of charged particles held around the Earth by its magnetic field, which can also do damage to humans and human technology. This environment makes human spaceflight very difficult biologically, and requires that everything done in space (with or without humans) include elaborate shielding. We must do artificially what the atmosphere does naturally. This vastly increases the cost of doing things in space, and has encouraged a shift from human to robot-based activity.

[1014] Daniel Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity* (Oxford University Press, 2018).

All objects in the universe exert the attractive pull of gravity. Gravity is the dominant force shaping the material context in outer space, and especially the areas surrounding celestial objects. Gravity is decisive for space activities because one has to overcome it to go anywhere in outer space. Because gravitational attraction falls off in a non-linear relationship to distance, its patterns and contours are best understood through the conceptual model of a 'gravity well.' The basic idea is that a celestial object exists at the bottom of the well, and the bigger the object (mass), the deeper the well. The depth of the gravity well represents the difficulty of escaping the attractive pull of the object. The gravity well means that the bulk of the energy required to get somewhere in outer space is expelled in the effort to escape the Earth's gravity.

Gravity also creates particular places in outer space; the 'Lagrange points' are "points of unusual orbital stability," where the gravitational attractions of celestial objects basically cancel each other out.[1015] Although these points represent a stable location for building things in space, they are (so far) only known theoretically. Virtually everything humans have done in space is within the gravity well, which includes all of Earth orbital space.

Gravitational dynamics make it possible to place artificial satellites into orbit around the Earth. Achieving a stable orbit requires reaching orbital velocity, which depends on the mass of the object to be orbited. Orbital velocity for the Earth is at least 17,500 miles per hour. At this velocity, an object can circumnavigate the planet in about 90 minutes. But there are several different types of orbit**,** or paths that a satellite can take in its revolutions around the Earth. Orbital paths have three features: height, eccentricity

[1015] Reynolds and Merges, *Outer Space*, 15.

(near-circular or elliptical), and inclination (angle relative to equator). The choice of orbit depends on the particular use of the satellite.

Most satellites are within 500 miles of the Earth's surface, which is relatively near given the vast expanse of outer space. EOS is commonly divided into three zones. Low Earth orbit (LEO), which extends up to 750 miles from sea level, contains the International Space Station, most scientific satellites, many weather satellites, and some reconnaissance and communications satellites. One type of LEO, polar orbit, has the highest possible inclination and passes over both poles. Because a satellite in polar orbit is always rotating north-south while the Earth rotates east-west, it can scan most of the surface of the Earth. This makes polar orbits especially useful for reconnaissance and remote sensing.[1016] A special type of polar orbit is called 'sun-synchronous,' because it always passes over the equator at the same local time. Although staying in sun-synchronous orbit requires regular adjustments, it is extremely valuable for consistent observation. This is especially useful for scientists, because it allows them to better track change in other factors by keeping the angle and strength of sunlight relatively constant.[1017]

Medium Earth orbit (MEO), from about 1,200 to 22,000 miles, contains most navigation satellites (like the US GPS and European Galileo), and some communications and space science satellites. Two MEOs are of particular interest. The semi-synchronous orbit has a 12-hour period, and has a high degree of consistency and predictability. This is the location of the GPS system satellites. The Molniya orbit, pioneered by the Russians, has a high inclination and high eccentricity, such that each 12-hour orbit

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[1016] Ibid.
[1017] Holli Biebeek, "Catalog of Earth Satellite Orbits," *Earth Observatory*, September 4, 2009.

includes a slow and high altitude portion that lingers over one hemisphere. Molniya orbit is useful for high latitude observation and communication, and currently contains Russian communications and Sirius radio satellites.

High Earth orbit also contains satellites for weather and communications, as well as scientific satellites that monitor solar activity. Perhaps the most important high Earth orbits are geo-synchronous, meaning that the "period of revolution of the satellite is equal to the period of rotation of the Earth."[1018] Although the eccentricity and inclination of a geo-synchronous satellite can vary, a unique type of geo-synchronous orbit is 'geo-stationary' (GSO). GSO is 22,300 miles above the Earth's surface, and has an eccentricity and inclination of zero; it is circular and rotates directly above the equator. Because GSO satellites are always above the same spot on the Earth's surface, they are extremely useful for regional weather monitoring and especially for communications satellites. A network of three communications satellites placed in GSO can achieve total coverage of the Earth's surface while remaining stationary over ground-based receivers. Without GSO, achieving continuous coverage over one location would require a large string of satellites. Individual slots in GSO are particularly valuable, but crowding can cause interference and undermine their value so the resource is finite.

Celestial bodies are a large physical outer space resource, and visions of visiting, colonizing, and exploiting them have long pervaded the Space Age. In addition to the planets that orbit our sun and other stars, and the moons that orbit those planets, asteroids populate the space environment. Humans have only known about asteroids for around 200 years, and initially they were a curiosity for astronomers. In the past three decades,

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[1018] Heather E. Hudson, *Communication Satellites: Their Development and Impact* (New York: Free Press [u.a.], 1990), 4.

however, scientists have increasingly catalogued 'near Earth objects' (asteroids and comets) that may present a risk of collision with the Earth. In these same decades, scientists first learned "the basic physical properties of asteroids, such as rotation rate, size, shape, composition, and origin."[1019] This knowledge – made possible by innovations in electronics and computing – supported the conceptualization of asteroids as a resource to be mined by humans.[1020] In comparison to other celestial bodies, asteroids are relatively accessible, have negligible gravity wells, and are therefore easy to move and easy to leave. Many of them are known to contain valuable minerals, and comets may contain useful materials like water, methane, and ammonia.

Space travel had been dreamed about since Johannes Kepler's 1634 novel *Somnium*, so at the beginning of the Space Age there were lots of mature ideas about what resources existed in space. Speculation about minerals on the moon and other celestial bodies drove excitement about a solution to terrestrial resource scarcity.[1021] So too did ideas about space-based solar power, which might be harnessed in space or beamed down to the planet.

But ultimately, the vast majority of resources exploited in space so far have been "spatial extension resources," or those whose value is a function of their geography.[1022] Satellites are useful because of their position 'above' and orbit around the planet. This position allows them to be used as tools of information collection and distribution, including navigation and mapping, point-to-point communication and broadcasting,

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[1019] Curtis Peebles, *Asteroids: A History* (Smithsonian, 2016), 239.
[1020] John S. Lewis, *Mining the Sky: Untold Riches from the Asteroids, Comets, and Planets* (Perseus Books, 1996).
[1021] Anthony R. Martin, "Space Resources and the Limits to Growth," *Journal of the British Interplanetary Society* 38 (1985): 243–52.
[1022] Buck, *The Global Commons an Introduction*, 3.

targeting and search and rescue, among other applications. Another feature of these actually-exploited and non-speculative resources is that their access and use depends on technology, such that the resource arguably did not exist before the technology existed to exploit it. Additional and speculative spatial extension resources – such as the Lagrange points, or shields to deflect electromagnetic radiation from the sun – also depend on the development and application of new technology. While this relationship between technology and resources also exists on the surface of the planet, it is especially pronounced in outer space. Unlike terra firma, outer space is solely accessible because of technology.[1023]

Technology

Space activities emerged very rapidly; in one lifetime, humans achieved heavier-than-air flight (1903), launched the first rocket through space (1944), sent objects into orbit (1957), and put a human on the moon (1969). The suddenness of access to space can be understood as a singular historical moment, and a "real qualitative change in human existence."[1024] The swift progress of the early years of the Space Age encouraged observers and enthusiasts to imagine wondrous new futures in space activity. In the late 1960s and early 1970s, popular and government forecasting about technological possibility was extremely optimistic, because observers assumed that the steep rate of progress would continue unabated.[1025] Although scholars noted that "it is difficult for the human mind to adjust" to the novelty of the situation, they were comfortable predicting a short time frame for reaching the moon and achieving inter-planetary travel.[1026] It was

[1023] Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity*, chap. 6.
[1024] Reynolds and Merges, *Outer Space*, 420.
[1025] Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity*, chap. 1.
[1026] Jessup and Taubenfeld, *Controls for Outer Space and the Antarctic Analogy*, 199.

believed that launches would get much easier, and that space would be filled with workers and residents in only a few decades. In the spirit of Jules Verne and H.G. Wells, space enthusiasts made extrapolations of technology based on what seemed possible at the time, and proclaimed that humans were on the brink of a "new and greater age of discovery."[1027]

Earliest Possible Time Periods of Various Soviet and U.S. Accomplishments in Outer Space

	Soviet[a]	U.S.[b]
1. Scientific Earth Satellites (IGY Commitment)	1957–58	1958
2. Reconnaissance Satellites[c]	1958–59	1959–61
3. Recoverable Aeromedical Satellites	1958–59	1959
4. Exploratory Lunar Probes or Lunar Satellites	1958–59	1958–59
5. "Soft" Lunar Landing	1959–60	early 1960
6. Communications Satellites	—	1959–60
7. Manned Recoverable Vehicles		
a. Capsule-type Satellites	1959–60[d]	
b. Glide-type Vehicles	1960–61	1960–63
8. Mars Probe	Aug. 1958[e]	Oct. 1960
9. Venus Probe	June 1959[e]	Jan. 1961
10. 25,000 pound Satellite—manned	1961–62	after 1965
11. Manned Circumlunar Flight	1961–62	1962–64
12. Manned Lunar Landing	after 1965	1968

SOURCE: NSC-5814/1, "Preliminary U.S. Policy on Outer Space," 18 Aug. 1958, p. 16: DDE Library, Office of The Special Assistant for National Security Affairs.
[a] Estimate by the Guided Missile Intelligence Committee of the IAC as of June 3, 1958.
[b] Source: Department of Defense, June 4, 1958.
[c] Defense comment: The United States plans to launch a reconnaissance satellite of approximately 3,000 pounds in later 1959. . . .
[d] The Joint Staff member of GMIC reserves his position on the date 1959.
[e] The Soviets most likely would attempt probes when Venus and Mars are in their most

Figure 20 – Expected timeline of space activities in 1958, From McDougall, Walter A. The Heavens and the Earth: A Political History of the Space Age. Baltimore, Md: Johns Hopkins University Press

These anticipations greatly under-estimated the physiological barriers to living in space and the challenge of affordable escape from the Earth's gravity well. They also

[1027] Ibid., 221.

over-estimated the feasibility of resource extraction, and the willingness of actors to spend large amounts of money to pursue space possibilities. Militaries in the United States and Soviet Union were the first to make major investments in research and development of space access technologies, because they could achieve significant benefits without needing to send any people to space. Eventually, the Space Age entered a plateau of incremental developments and unexpected setbacks, during which time disappointed space enthusiasts were forced to temper their expectations for the near future. The US Space Shuttle program promised routine access to space, but only five were built, and two were lost in catastrophic accidents. Perennial commitments to build a moon base or send humans to Mars remain unfulfilled. Despite this history of dashed expectations, a coterie of 'space expansionists' continues to devise schemes and lobby for support for more space technology.[1028]

Building a regime to effectively manage current and future space technologies requires having a functional relationship with the evolution of space technology. A regime can either be flexible (which the Outer Space Treaty is not), or just well-suited to emerging forms of technological use of space. Technologies create the basic conditions for all activities in EOS. In particular, the distribution and composition of space access technology influences the type of practices, content of interests, and structure of problems in outer space. Insofar as the outer space regime ignores, overlooks, or cannot see these patterns, it is unlikely to achieve its basic goals.

The geophysical features of orbital space create obstacles to access, which must be overcome by technology. In effect, these features set a design agenda for space technologies: if technologies cannot do certain things, humans or their technological

[1028] Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity*.

proxies cannot get to and operate in orbital space. Escaping the Earth's gravity requires tremendous velocities, and operating in space requires shielding from extreme temperatures. Because of the extreme environment and advanced technology required to access it, outer space activities have been very expensive. These high costs partially explain two general trends in space technology. First, the initial dominance of military activities over commercial applications is at least partially explained by the ability of the former to invest in high cost, high-risk ventures without guaranteed financial return. Second, the expense and distinctiveness of space technology impede its ready and easy diffusion among states and other actors, especially compared to access technology in other domains.

Space vehicle technology faces three major tasks: escaping gravity to reach orbital space, maintaining structural integrity while there, and in some cases, safely returning to Earth through the atmosphere. Each step entails significant design and materials requirements for space vehicles. Launching requires powerful rockets and large amounts of fuel, and high launch costs have persisted throughout the Space Age and obstructed the diffusion of access to space. The approximate cost of putting a pound in orbit is $10,000, and roughly 85 percent of a rocket's weight at the launch pad is fuel.[1029] Because the pull of gravity is consistent, reducing launch costs can only be achieved by decreasing the weight of payloads to minimize the amount of fuel required, or through reusable vehicles. Operations in orbit require fuel and situational awareness, to maintain particular orbits or avoid dangerous space debris. Re-entry seems like the easy part, because vehicles are moving in the direction gravity pulls them. But moving from

[1029] Don Pettit, "The Tyranny of the Rocket Equation," National Aeronautics and Space Administration, *Expedition 30*, (May 1, 2012); Sarah Kramer and Dave Mosher, "Here's How Much Money It Actually Costs to Launch Stuff into Space," *Business Insider*, July 20, 2016.

frictionless space into a friction-filled atmosphere is actually quite arduous, because friction causes a great increase in temperature. Indeed, space vehicles become sheathed in plasma for part of re-entry. This requires materials that can withstand extreme heat and pressure.

The speed and ascendency of objects in orbital space makes this domain an attractive location for weapons, which may be based in orbital space or simply travel through it (like an ICBM). The perspective from space is also valuable: the information gathered by satellites operates as a 'force multiplier' for existing weapons technologies, providing targeting information and performing communication functions. It also supports a more general type of reconnaissance, which was especially valuable for the United States in the early Cold War. Although military interests and actors were the first to develop and use space technology, it has been estimated that ninety percent of this technology is "dual use," meaning that the same capabilities can be used for non-military interests.[1030] Two primary examples of dual use technology are rockets and satellites.

Satellites – objects placed in orbit around the Earth – currently have three major applications: remote sensing, communications, and navigation. All three types of satellites began orbiting in the 1960s, although navigation and remote sensing satellites were the exclusive province of national militaries during this period. 'Remote sensing' includes both looking 'out' and looking 'in,' and is useful for weather forecasting, reconnaissance, and astronomy. Communications and navigation are useful for coordinating military activities and targeting weapons, but also for international television broadcasts and finding one's way in a new city. Indeed, the information

[1030] Klaus Dodds, "Introduction - The Governance of the Global Commons: Much Unfinished Business?: The Governance of the Global Commons," *Global Policy* 3, no. 1 (February 2012): 59.

gathered and transmitted via satellite is utilized for a wide variety of purposes, and satisfies the interests of a large and diverse set of actors. To perform their commercial, military, and monitoring functions, satellites utilize delicate and expensive hardware, which opens them to risk of damage, and their owners to risk of major losses. In general, however, recent advances in computing, manufacturing, and corporate business models have radically increased access to satellites.[1031] Launch costs remain high, but are less of a barrier as payloads get lighter and more sophisticated and investment increases.

Space enthusiasts are currently heralding a ‘Second Space Age,’ which promises wide-scale exploitation and near-term colonization.[1032] These predictions, as in the 1960s, tend to be saturated with optimism and imaginative thinking about technological innovation.[1033] Space anticipations are also inspired by the significant development of private space activities, driven in large part by billionaire space enthusiasts. The prospect of space tourism is tied to continued development of aerospace vehicles. The idea of solar power collecting satellites is often floated as a solution to climate change. The biggest bottleneck for access to space has always been limitations in launch technology, which has not advanced significantly since the early Space Age.[1034] But some still predict "orders of magnitude reduction of launch costs" before 2020.[1035] There remains a persistent belief in the possibility of new launch technologies, given the right amount of

[1031] Dave Baiocchi and William Welser, “The Democratization of Space,” *Foreign Affairs*, June 2015.
[1032] Julian Guthrie, *How to Make a Spaceship: A Band of Renegades, an Epic Race, and the Birth of Private Space Flight* (New York: Penguin Press, 2016); Charles P. Wohlforth and Amanda R. Hendrix, *Beyond Earth: Our Path to a New Home in the Planets*, First Edition (New York: Pantheon Books, 2016).
[1033] Arthur C. Clarke, *The Promise of Space* (New York: Harper and Row, 1968).
[1034] Walter A. McDougall, *The Heavens and the Earth: A Political History of the Space Age*, Johns Hopkins paperbacks ed (Baltimore, Md: Johns Hopkins University Press, 1997), xvii.
[1035] Ivan Bekey, “The Long-Term Outlook for Commercial Space,” in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 196.

investment.[1036] Space enthusiasts envision a breakthrough in access in the form of 'space elevators,' among other ideas, which will facilitate space-based industry and the colonization of space stations. The raw materials for these projects can be hypothetically gathered in space, including energy from solar collectors and raw materials from the mining of asteroids. Many scientists and engineers express skepticism about these plans, especially colonization, but some future technologies – such as asteroid mining – may be more realistic medium-term prospects.

Ineffectiveness

It is inherently difficult to evaluate the success of a governance regime compared to the counterfactuals, which include (1) no regime, (2) the same regime implemented sooner, and (3) a different regime altogether. This project evaluates the OST-centered regime by reference to its own goals and purposes at the time of its formation: peaceful, sustainable, and equitable use.[1037] The outer space regime has a mixed history; both successes and failures can be identified. In general, there is a good record of compliance with international law in outer space. While this seems like a good metric of effectiveness, the permissiveness and ambiguity of the regime make non-compliance unlikely. The OST regime prohibits few specific things, and "permits states wide discretion in initiating, continuing, dispensing with, and defining all forms of outer space activity."[1038] The 'province of mankind' designation was accepted by the superpowers "on the general assumption that it will not really burden their programs and…they

[1036] US Congress Office of Technology Assessment, *Launch Options for the Future: Buyer's Guide* (Washington, D.C.: U.S. Government Printing Office, 1988).
[1037] The Outer Space Treaty says explicitly in the preamble that use of outer space is for the "benefit of all peoples" and also for "peaceful purposes." While sustainable use was not originally an explicit goal of the regime, the development of norms regarding space debris mitigation indicate that sustainable use has become a customary principle.
[1038] Peterson, "The Use of Analogies in Developing Outer Space Law," 246.

themselves will determine unilaterally how it is to be implemented."[1039] But the OST regime did contribute to strategic stability during the Cold War; its institutions are credited with diminishing Cold War military rivalry and helping channel superpower competition into the realm of civilian science. Two of its component treaties – the OST and LTBT – are also important parts of the nuclear arms control regime. Finally, the outer space regime can be understood as a success because of its durability. Core regime components, such as non-appropriation, enjoy broad compliance and status as customary international law. But that durability is also a sign of rigidity, and science and technology in outer space have advanced considerably since the dense early period of regime formation.

Several decades after most of the outer space regime entered into force, technological change, scientific knowledge, and ambiguous political geographies are undermining its effectiveness. The OST regime is confronted with new uses, new problems, and newly understood problems in orbital space. Each of these developments implicates the requirements for a functional regime that achieves peaceful, equitable, and sustainable use of EOS. The OST has no "built-in system for consultations and regular interactions," because it was not designed to be easily updated in the light of new scientific knowledge or technological capabilities.[1040] This is a regime design flaw because the interests of an increasingly large space 'public,' and the collective problems they face, change over time as a result of technological advancement and improved

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[1039] Seyom Brown et al., eds., *Regimes for the Ocean, Outer Space, and Weather* (Washington: Brookings Institution, 1977), 130.
[1040] Sergey Batsanov, "The Outer Space Treaty: Then and Now," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 54.

scientific knowledge. The result is a regime that is ineffective in operation, and incomplete in scope.

The outer space regime was built too fast, and then too slow. Its core agreements were negotiated during a period of strong internationalism, during which states could gain prestige through international cooperation.[1041] The OST was signed, ratified, and entered into forced in the span of a single year. It took less than a decade to negotiate the rest of the OST-regime, and since the 1970s no binding international laws or treaties have been added. This concentrated burst of regime formation, followed by decades of inactivity, created three basic regime pathologies. First, the OST regime includes an anachronistic, but embedded, image of outer space that makes it poorly suited to current realities. This 'frozen ontology' of EOS includes the ideas that outer space is an infinite sink that contains no major threats, and states are the only actors. Second, the OST regime does not account for changes in the composition and distribution of space technology, and generally permits any technological uses that are not specifically outlawed. Third, the regime relies on a simplistic form of nationalization, which overly constrains the scope of both restrictions and obligations. These general regime pathologies are evident in four cases or issue areas: militarization, space debris, commercialization, and asteroid collision.

The regime failed to de-militarize, or even de-weaponize outer space. Navigation, communication, and remote sensing satellites are vital supports to advanced military operations. Ballistic missiles can still traverse orbital space without legal violation or social disapprobation.[1042] Anti-satellite weapons (ASATs), which come in a variety of

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[1041] Jessup and Taubenfeld, *Controls for Outer Space and the Antarctic Analogy*, 276.
[1042] Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity*.

forms and basing schemes, are not currently prohibited. Perhaps most concerning is the general recognition that the OST only bans the emplacement of weapons of mass destruction in space, leaving room for highly advanced conventional weapons. Indeed, the space policy of US President George W. Bush was widely seen as a move towards weaponizing orbital space.[1043] The fear of an arms race in outer space continues to dominate discussion of space issues in the United Nations Conference on Disarmament.

The regime has failed to prevent the multiplication of debris present in orbital space. Debris has been added to the space environment since the first launches in the 1950s and 1960s. Space debris has multiple sources, most of which are intentional or known by-products of launches, tests, and space systems past their useable lifetimes. The high speed of objects in the frictionless terrain of outer space makes collisions extremely damaging, and increases the risk of congestion and disruption. The biggest risk is 'breeding' debris, which occurs when collisions cause more debris, which cause more collisions. The cascade or "domino effect" could degrade the usability of the space environment for all actors, a problem which was recognized in the late 1970s. The problem of debris is the subject of scientific consensus, and yet the regime includes no binding requirements regarding debris creation, and no collective efforts to find a solution to the problem.

The regime is ambiguous regarding the activities of commercial space actors. While companies involved in launching payloads do require authorization by the 'launching state,' the norms to which a state is responsible are undeveloped, and there is a reasonable risk of 'flags of convenience' or 'spaceports of convenience' system emerging. In terms of commercial resource extraction, there remains substantial

[1043] Moltz, *The Politics of Space Security*, 96.

disagreement about whether, and under what conditions, a company can extract resources from a celestial body and claim them as private property. As asteroid mining moves from the speculative to the prototype phase, questions about ownership over entire asteroids will emerge. Companies are asserting that they can claim asteroids, while a surface reading of the treaty text suggests otherwise.

Asteroids present a risk as well as an opportunity. OST declares that space is to be accessed and used for the benefit of all humankind, but is silent on the idea of risk and threat for all humankind. There is nothing about the risk of asteroid collision in the original treaty, because of geophysical ignorance of the threat at the time of regime formation. While the technology exists to track dangerous asteroids and comets, there is no dedicated international mechanism for doing so. Although there are many proposals for asteroid deflection when the need arises, no commercial or national actor has invested in the development of a capability that would protect the planet and benefit all of its inhabitants. The asteroid risk ought to be an easy case, because it is a well-understood threat to all humans, which can be mitigated by collective investment in tracking and deflection. And yet, the regime says and requires nothing regarding asteroid collision.

Table 3 - Evaluation of outer space regime effectiveness

	Success	**Failure**
Militarization	No superpower conflict No WMD basing No nuclear testing ASAT moratorium	Risk of PAROS ASAT testing Permits conventional weapons No ASAT ban
Commercialization	Growing markets: launch, payload, operation	Regulatory uncertainty Risk of privatization Flags/ports of convenience

Space environment	Some mitigation	Debris mitigation Debris remediation Situational awareness Collision avoidance
Asteroid deflection	Some detection Some deflection planning	Underfunded detection No collective action No deflection plan

Militarization

The outer space regime has a "military heritage."[1044] Cold War rivalry was a crucial impetus for doing things in space, and military expenditures funded targeted research and the construction of the first space rockets and satellites. Military security and strategy drove much of the early regime building in outer space, especially concerning reconnaissance and nuclear weapons testing and basing (UNGA Resolution 1884, LTBT, OST). EOS activities quickly came to be understood as a source of both security and insecurity. The ascendant position of satellites over territorial states was an advantage but also brought vulnerability: satellites could target and/or deliver weapons from space, and were vulnerable to weapons from the ground. Because satellites were very useful for commercial and military purposes, but very vulnerable to interference or destruction, users had a strong incentive to cooperate to achieve security. And yet the original regime is extremely permissive; it does not mention ICBMs or ASAT weapons, and it only prohibits the basing of weapons of mass destruction in space. During the Cold War, both superpowers "demonstrated creativity, persistence, and open checkbooks in

[1044] United Nations Institute for Disarmament Research, ed., *Security in Space: The next Generation: Conference Report 31 March-1 April 2008* (New York: United Nations, 2008), xxvii.

pursuit of diverse ASAT weapon systems."[1045] But they did not use ASATs against one another.

Although a de facto ASAT moratorium existed between the superpowers for many decades, "the reemergence of ASAT development and testing" in the 21st century calls into question the durability (or even existence) of the moratorium.[1046] While some argue that the moratorium can still function as customary international law, the United States opposes any recognized agreement.[1047] And the weak reaction to ASAT tests by the international community in the recent past demonstrates that customary international law against the development of such weapons is weak at best.[1048] There is currently a strong sense that challenges to traditional space security are increasing.[1049] The international community is "haunted" by the specter of weaponization, which may be triggered by strategic rivalry between the US and China, unintentional but misinterpreted collisions, or new and hostile rogue state actors.[1050] The 2006 US National Space Policy added to concerns by approaching the "threshold of weaponization" without actually crossing it.[1051] Indeed, there remain tendencies and attitudes in the US military that favor a form of spacepower or space command.[1052] China, Russia, and the United States all

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[1045] David A. Koplow, "Asat-Isfaction: Customary International Law and the Regulation of Anti-Satellite Weapons," *Michigan Journal of International Law* 30, no. 4 (2009): 1208.
[1046] John M. Meyer, *Engaging the Everyday: Environmental Social Criticism and the Resonance Dilemma* (MIT Press, 2015), 9.
[1047] Koplow, "Asat-Isfaction: Customary International Law and the Regulation of Anti-Satellite Weapons."
[1048] United Nations Institute for Disarmament Research, *Security in Space*, xxxii.
[1049] Moltz, *The Politics of Space Security*, 11.
[1050] Zhang Ju'nan, "Fundamental Ways to Ensure Outer Space Security: Negotiating and Concluding a Legally Binding International Instrument," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007); Michael Nacht, "U.S. and China in Space: Cooperation, Competition or Both?" (Stimson Center, 2013); Micah Zenko, "Dangerous Space Incidents," Contingency Planning Memorandum, Center for Preventative Action (Washington, D.C.: Council on Foreign Relations, April 2014).
[1051] Moltz, *The Politics of Space Security*, 296.
[1052] Koplow, "Asat-Isfaction: Customary International Law and the Regulation of Anti-Satellite Weapons."

possess ASAT capabilities, latent or explicit.[1053] In 2010, India announced the launch of an ASAT program. Even without adding new actors, ASAT capabilities are substantial. New micro-satellites increase the number and decrease the distinctiveness of potential ASAT weapons.[1054] Because kinetic impact is so damaging to satellites, almost anything can be used as an anti-satellite weapon, so almost any space user can develop ASAT capability.

Concern regarding the risk of ASAT use has placed the prevention of an arms race in outer space (PAROS) at the top of the agenda for the United Nations Conference on Disarmament (which has been stalled on the issue for over a decade, because of US opposition). New military competition in space is thought to be inevitable without a new and more comprehensive legal regime.[1055] ASATs were already being researched at the time of regime formation, so why is OST ineffective at PAROS? The basic security situation for satellites (vulnerability) has not changed substantially in the last several decades, although the number and sophistication of ASATs have. With regard to achieving space security, some argue "technology has outpaced diplomacy."[1056] But the problem may be more fundamental than a lag between technological change and regime augmentation.

Several features of the outer space regime undermine its ability to redress sources of military insecurity in space. First, the Cold War created a division between civilian and

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[1053] Dougherty, "War in Space: Anti-Satellite Weapons."
[1054] David R. Higgins, "Future War: Micro-Satellites & the Militarization of Space," *Modern War*, August 2013.
[1055] Nina Tannenwald, "Law Versus Power on the High Frontier: The Case for a Rule-Based Regime for Outer Space," *The Yale Journal of International Law* 29 (2004): 364.
[1056] Jessica West, "The Space Security Index: Changing Trends in Space Security and the OST," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 126.

Table 1. Military perceptions regarding the utility of outer space

Role	Typical airpower mission	Contemporary space mission
Control of environment	Counter air missions	Counter space missions
Applying combat power	Air-based force application	Space-based force application
Multiplying combat power	Airborne combat support	Space-based terrestrial combat support or force

Figure 21 - Airpower analogies, From Nair, Kiran. "Putting Current Space Militarization and Weaponization Dynamics in Perspective: An Approach to Space Security." In Celebrating the Space Age

military space programs and issues.[1057] Domestically, NASA and the Department of Defense (specifically the Air Force) each handle space activities. Internationally, COPUOS deals with all space issues except for weaponization or militarization, which is a topic for the Conference on Disarmament. This decreases the linkages with other issues, and increases the influence of military actors and interests. Second, military doctrines regarding outer space "primarily build upon airpower doctrines," a phenomenon most obvious in the United States, but also modeled by other militaries with space assets.[1058] Airpower doctrine emphasizes the strategic advantage of controlling the "high ground," and calls for both anti-space and space-based forces. This analogy may distort the calculations relating force composition, structure, and posture to security objectives. Third, Article 4 of OST outlaws nuclear weapons and other weapons of mass destruction in orbit, but in outer space "just about anything could be a weapon."[1059] This feature of the OST regime cuts to the heart of the issue regarding continued insecurity in space: existing and proposed institutions rely on the distinctiveness of the threat.

[1057] McDougall, *The Heavens and the Earth*, xvii.
[1058] Kiran Nair, "Putting Current Space Militarization and Weaponization Dynamics in Perspective: An Approach to Space Security," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 100.
[1059] United Nations Institute for Disarmament Research, *Security in Space*, xxxiii.

The OST did seek to outlaw weapons in space, but determining what was a weapon and how to ban them presented a challenge for negotiators. The main axis of the early debate was between the peaceful/aggressive distinction preferred by the United States, and the military/non-military distinction preferred by the Soviet Union. Although the peaceful/aggressive distinction won out, it triggered a "long and continuous debate" about the meaning of each term.[1060] The vast majority of space technology is 'dual use,' meaning that it is difficult to distinguish objects based on their potential for peaceful or aggressive use.[1061] And although the superpowers wanted to protect their vulnerable military and commercial satellites, they also wanted to maintain the advantages of the 'high ground' perspective and route (for ICBMs). The debate over the meaning of 'peaceful' space activities demonstrated the futility of outlawing specific *intentions* in space, and the dual use nature of most space assets makes banning *objects* a non-starter. Both of these strategies suffer from a lack of distinctiveness; it is difficult or impossible to tell whether an object is intended to be used, or will someday be used, as a space weapon. While a few commentators argue that some types of in-orbit ASATs are distinguishable by the configuration of their rocket thrusters, this does not include the full range of potential ASAT systems.[1062] Most conclude that defining space weapons in an effort to control them is not feasible.[1063] So while the OST regime requires that 'space

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[1060] Hewa Palihakkara, "Space Security: Perspectives of Developing Countries," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty: Conference Report, 2-3 April 2007*, ed. United Nations Institute for Disarmament Research (New York ; Geneva: United Nations, 2007), 85.
[1061] Dodds, "Introduction - The Governance of the Global Commons," 59.
[1062] Phillip J. Baines, "The Security Dimensions of Space Traffic Management," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 196–97.
[1063] Peter Hays, "Developments in BMD," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR,

activities' and 'space objects' must be for peaceful purposes, the only operative and effective prohibition has been the clear rule against placing weapons of mass destruction in orbit.

Proponents of a new anti-ASAT treaty suggest that *activities* should be regulated or prohibited, including those that "intentionally create debris" and those that use force against other space objects.[1064] There not currently enough momentum to expect a treaty in the near or medium term, primarily because of US opposition. But this strategy also replicates the distinctiveness issue. It will be difficult or impossible to discern whether a collision was intentional or unintentional; behavior can be threatening as a result of negligence or careful planning. There is a problem of discrimination, where a test or targeted use may indiscriminately harm non-target users. There is also a problem of attribution, because the prevalence of ambient and dangerous space debris increases the risk of unintentional damage, which may be misperceived as intentional and planned. The basic problem is the focus on regulating the intended activities of objects controlled by actors, which appears in the existing regime and also proposals for its augmentation. This represents a functional instead of spatial approach to governance in outer space. Understanding the difference between these approaches demonstrates that another way is possible.

The functionalist approach seeks to regulate on the basis of what an object is doing, rather than where it is located, and therefore depends on the capabilities and

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2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 143; Michael Krepon, "A Code of Conduct for Responsible Space-Faring Nations," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 168.

[1064] Gregory D. Koblentz, "Strategic Stability in the Second Nuclear Age," Council Special Report (Council on Foreign Relations, November 2014), 35; United Nations Institute for Disarmament Research, *Security in Space*, xxx.

distinctiveness of space access technology. A functionalist approach outlaws weaponization of space by focusing on the weaponization of 'space objects.' This presents a category challenge: what is a 'space' object? A customary understanding has developed "to the effect that any object in orbit is in space."[1065] This type of definition has been described as "solipsism" because it depends on what humans can do with their technology.[1066] Of course, what space objects can do changes with technological advancement; for example, the von Karman Primary Jurisdiction line, often used to demarcate the boundary of outer space, begins where conventional aircraft cannot currently venture.[1067] The main challenge to the functionalist approach to delimitation is the so-called 'aerospace plane' or 'near space vehicle,' an as-yet un-achieved technological advance that would facilitate access to the legal gray area where satellites cannot orbit and planes cannot fly.[1068]

The spatial approach, which is not present in the existing outer space regime, seeks a non-arbitrary dividing line, such as the density of air molecules, the altitude where air molecules stop rotating with the Earth, the chemical composition of the atmosphere, or the point at which meteors become luminous.[1069] But scientists do not agree on the precise locations for most of these thresholds, many of which are constantly changing because of atmospheric dynamism. And no one feature commands superior logic or legitimacy for delimiting the outer space domain. Neither the spatial nor the

[1065] Reynolds and Merges, *Outer Space*, 12.
[1066] Ibid., 6.
[1067] Bodansky, Brunnée, and Hey, *The Oxford Handbook of International Environmental Law*, 247.
[1068] Jinyuan Su, "Near Space as a Sui Generis Zone: A Tri-Layer Approach of Delimitation," *Space Policy* 29, no. 2 (May 2013): 90.; John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 100.
[1069] Beery, "Unearthing Global Natures," 97.

functional approach to delineating outer space is obvious or unchanging. The geophysical boundary is fuzzy, and technological capability is fluid over time.

As a possible alternative to the existing OST regime, a spatial approach would eliminate the distinctiveness issue by prioritizing the features of the EOS environment as relatively free of debris, radioactivity, and electro-magnetic pulses. Defining the domain of outer space may seem arbitrary, but should not be understood as difficult. There are many geophysical differences between airspace and orbital space that make the two domains naturally distinct. Instead of the security of individual space assets, a spatial approach would prioritize a broader form of environmental security. It would thus prohibit intentional or negligent maneuvers that risk producing additional contaminants, especially debris. It would be the creation of debris, electromagnetic pulse, or radioactivity that makes a state liable or punishable, not the intention or the character of the object, or even the activity. Penalizing or prohibiting based on outcome relative to the outer space environment resolves the distinctiveness issue and collapses the civilian/military distinction.

Space debris

Orbital space is a unique security environment where users are highly vulnerable, and security is more interdependent than in other realms.[1070] The lack of an atmosphere means that space objects can travel very fast in proportion to the volume they traverse, so the 'effective distance' in near Earth space is small.[1071] This increases the risks of congestion and disruption. One form of non-military insecurity is the risk of space debris, which theoretically 'breed' when collisions cause cascades of break up. NASA defines

[1070] Moltz, *The Politics of Space Security*, 11.
[1071] Deudney, *Dark Skies: Space Expansionism, Planetary Geopolitics and the Ends of Humanity*.

space debris as "artificial objects, including derelict spacecraft and spent launch vehicle orbital stages, left in orbit which no longer serve a useful purpose." Space debris is not biodegradable, and the only natural mechanism for its removal is orbital decay, through which debris in LEO eventually falls into (and often burns up in) the atmosphere.[1072] Debris in higher orbits will eventually decay, but the timespans are much longer. In GEO, for example, debris is relatively permanent.[1073] Many of these objects are very small, but dangerous because of their high speed and the difficulty involved in tracking them. Indeed, space debris tends to cluster in the most valuable orbits. Space debris is an "indiscriminate threat," an enormous and, for many decades, under-appreciated problem for which the existing outer space regime has no solution.[1074] The regime has been ineffective at securing safe access to the space environment, in large part because the delayed arrival of consensus about the threat meant that interests were poorly formed at the time of negotiation.

The construction of the OST regime occurred during a period of ignorance about the geophysical-technological interaction that creates the space debris problem. NASA scientists recognized the hazard of natural space debris in the early 1960s, but anthropogenic debris was not an object of focused research until the mid-1970s.[1075] The problem of multiplying orbital space debris was first described by NASA scientists

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[1072] "Flying Blind: The Tragedy of the Commons Meets the Final Frontier," *The Economist*, February 19, 2009.
[1073] Eligar Sadeh, "Spacepower and the Environment," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 262.
[1074] Nair, "Putting Current Space Militarization and Weaponization Dynamics in Perspective: An Approach to Space Security," 105.
[1075] Elmer H. Davison and Paul C. Winslow, "Space Debris Hazard Evaluation," Technical Report (Cleveland, OH: NASA Lewis Research Center, December 1, 1961).; T.D. Bess, "Mass Distribution of Orbiting Man-Made Space Debris," Technical Report (Langley Station, VA: NASA Langley Research Center, December 1975).; D.R. Brooks, "A Comparison of Spacecraft Penetration Hazards Due to Meteoroids and Manmade Earth-Orbiting Objects," Technical Report (Langley Station, VA: NASA Langley Research Center, November 1976).

Donald Kessler and Burton Cour-Palais in their 1978 paper "Collision Frequency of Artificial Satellites: The Creation of a Debris Belt." The phenomenon of 'breeding' or multiplying debris became known as the 'Kessler Syndrome.' According to Kessler himself, "nobody believed it initially."[1076] The idea of risk and limitation in orbital space contradicted the prevailing view that space was a "limitless environment" and a "virtually infinite sink for pollution."[1077] At the time of regime formation, the high seas analogy did not invite consideration of the risk of environmental pollution. During this period, the ocean was conceived as a "great neutralizer, with virtually unlimited ability to absorb noxious substances."[1078]

Despite this general optimism, the COPUOS Scientific and Technical subcommittee started discussing the issue of debris in 1980.[1079] But the "flow of documents and papers" over the next decade "failed to stimulate speedy policy development at the UN."[1080] There was some unilateral, non-binding action by concerned space actors. NASA and the Department of Defense initiated mitigation practices in 1982, and US Presidents Ronald Reagan and George H.W. Bush called for others to adopt techniques that minimize debris.[1081] By the late 1980s and early 1990s, more and more scientists, scholars, and diplomats were growing concerned.[1082] Articles in the journal *Space Policy* described debris as a "serious threat" about which "concerted action

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[1076] Gregory Mone, "Donald Kessler: Prophet of Space Trash.," *Discover* 32, no. 10 (December 2011): 15.
[1077] Batsanov, "The Outer Space Treaty: Then and Now," 51; Martin, "Space Resources and the Limits to Growth."
[1078] Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (Oxford: Oxford Univ. Press, 2013), 99.
[1079] Lubos Perek, "Space Debris and the World Community," *Space Policy*, February 1991, 9.
[1080] Ibid., 10.
[1081] Sadeh, "Spacepower and the Environment," 262.
[1082] Nicholas L. Johnson and Darren S. McKnight, *Artificial Space Debris*, Orbit Foundation Series (Malabar, Fla: Orbit Book Co, 1987).

is urgently needed."[1083] Even then, observers remarked on the disconnection between the "wide consensus" among scientists, and the inaction of space actors, policymakers, and diplomats.[1084] The United States Office of Technology Assessment recommended an "international educational program" to make "the hazards of space debris better understood."[1085]

During the 1990s the space law and policy community engaged in a general debate about how to define and achieve space security. By the late 1990s, a common understanding of the space debris problem prompted more widespread calls for a regulatory regime.[1086] But disagreement about the actual extent of the threat still impeded progress on specific norms and rules.[1087] Groups working on the debris problem included the Science and Technology subcommittee of COPUOS, the Inter-Agency Space Debris Coordination Committee, and the International Organization for Standardization. In 2007, COPUOS and later the UNGA endorsed a set of Space Debris Mitigation Guidelines, which are non-binding 'rules of the road' that encourage the adoption of practices and techniques that reduce debris creation (Resolution 62/217).

These non-binding augmentations to the outer space regime are insufficient to address the debris problem. While the Space Debris Mitigation Guidelines decrease the addition of debris from new launches, they are inadequate for preventing debris multiplication from in-orbit collisions. Kessler and other NASA scientists argue that to prevent the continued growth of orbital debris would require "100% compliance" with

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[1083] Elmar Vitt, "Space Debris: Physical and Legal Considerations," *Space Policy*, May 1989, 129; Perek, "Space Debris and the World Community," 9.
[1084] Perek, "Space Debris and the World Community," 10.
[1085] Office of Technology Assessment, "Orbiting Debris: A Space Environmental Problem," Background Paper (Washington, D.C.: U.S Government Printing Office, September 1900).
[1086] Reynolds and Merges, *Outer Space*, 209.
[1087] Vogler, *The Global Commons*, 106.

the Space Debris Mitigation Guidelines, in addition to an active debris removal program.[1088] And such compliance is increasingly unlikely, given the expanding number of space actors and types of space activities. Small satellites may be a special concern. Planetary Resources Inc. is investing in the creation of small 3-D printed space objects, and India just launched over 100 small satellites at one time.[1089] These satellites radically increase the number of objects in orbit, and they are also unlikely to contain the necessary fuel and thrusters for post-mission disposal and active collision avoidance. Indeed, very few operational satellites have the capability to dispose of themselves post-mission, either by increasing their orbital decay or by moving to a 'graveyard orbit.' And "most of the current population does not have the capability to maneuver" for collision avoidance.[1090] Practical, economical, and effective debris remediation technologies do not yet exist.[1091]

Even with debris mitigation, collision avoidance, and remediation techniques, a basic condition of effectiveness is absent. One of the major obstacles to solving the debris problem is insufficient and uncoordinated 'space situational awareness,' or mapping and tracking of space objects. The United States maintains the most complete database of space objects, including active and operational space objects as well as debris. But even the US catalog does not track objects smaller than 10 centimeters, despite the technical ability to track objects as small as 5 centimeters.[1092] No existing catalog of space objects is exhaustive, and most have discrepancies regarding numbers, sources, and orbits of

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[1088] Donald J. Kessler et al., "The Kessler Synodrome: Implications to Future Space Operations," in *AAS 10-016* (33rd Annual AA Guidance and Control Conference, Breckenridge, Colorado: American Astronautical Society, 2010), 14.
[1089] Ram S. Jakhu, Joseph N. Pelton, and Yaw Otu Mankata Nyampong, *Space Mining and Its Regulation* (Springer Praxis Books, 2017), 65; Ellen Barry, "India Launches 104 Satellites From a Single Rocket, Ramping Up a Space Race," *The New York Times*, February 15, 2017,.
[1090] Kessler et al., "The Kessler Synodrome: Implications to Future Space Operations," 13–14.
[1091] United Nations Institute for Disarmament Research, *Security in Space*, xxix.
[1092] Sadeh, "Spacepower and the Environment," 261.

debris.[1093] A coordinated system that collects and disseminates data about space objects is an important pre-requisite for debris mitigation and removal, but it will require enhanced communication and cooperation among space actors.[1094] The information has to be comprehensive if it is to work, and a catalog has to work to gain credibility and authority among space users. A high level of accuracy in predicting collisions will be necessary to "minimize the number of false maneuvers and gain the confidence of the payload operators."[1095]

The absence of investment in post-mission disposal, collision avoidance, space situational awareness, and remediation technologies can be explained by incoherent interest formation. Awareness of and interest in the debris issue is low, even among scientists; "the scale and severity of this problem does not appear to be widely understood."[1096] If awareness and interest were high, the 2007 Chinese ASAT test and 2009 Iridium/Kosmos collision would have generated a public response.[1097] This situation demonstrates the limitations of the expanded notion of space security that accompanied the formation of the OST regime. In the early Space Age, events like the Starfish Prime test (1962) and the Apollo 1 explosion (1967) generated a newfound commonality of interests, which expanded the notion of security to include reliable and safe access to space.[1098] But this understanding of collective security – evident in treaties like LTBT, OST, and the Rescue Agreement – did not reach the level of environmental

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[1093] Brian Weeden, "Overview of the Legal and Policy Challenges of Orbital Debris Removal," *Space Policy* 27 (2011): 41.
[1094] Moltz, *The Politics of Space Security*, 310.
[1095] Kessler et al., "The Kessler Synodrome: Implications to Future Space Operations," 14.
[1096] David Wright, "Orbital Debris Produced by Kinetic-Energy Anti-Satellite Weapons," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 156.
[1097] United Nations Institute for Disarmament Research, *Security in Space*, xxii.
[1098] Moltz, *The Politics of Space Security*, 137, 302.

security, which focuses on the quality of the environment instead of just the safety of space actors. Environmental security did not become the framework for understanding risks in outer space in part because debris was not a recognized problem. But the absence of an environmental security framework has decreased the visibility of the problem, even after the community of space scientists recognized the magnitude of the risk.

An environmental approach to space security could potentially contribute to the development of a more coherent and urgent collective interest surrounding space debris, and is especially suited to a domain like EOS that includes mostly spatial extension resources. This view was introduced in the late 1980s and early 1990s, and proposes seeing the debris problem as "environmental in character."[1099] Outer space is thereby cast as a "natural environment which may be subject to detrimental changes caused by spaceflight activities."[1100] Defining outer space as "an ecological resource" would increase "understanding of the value of the environment itself" and import broad and long-term understandings of human interests from the environmental movement.[1101] The environmental perspective on outer space would, for example, highlight "the responsibilities of this first space generation to all future generations."[1102] This approach understands space security as an environmental management problem.[1103] When viewed from the perspective of any single actor, space debris appears as a diffuse and distant vulnerability. Preserving the space environment for future use depends on "every state's

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[1099] Perek, "Space Debris and the World Community," 10.
[1100] Vitt, "Space Debris: Physical and Legal Considerations," 129.
[1101] David Enrico Reibel, "Environmental Regulation of Space Activity: The Case of Orbital Debris," *Stanford Environmental Law Journal* 10, no. 97 (1991): 134, 97.
[1102] Ibid., 136.
[1103] Moltz, *The Politics of Space Security*, 40.

appreciation that its own self-interest lies in preserving this precious common good."[1104] When the geophysical reality of EOS is foregrounded, "the central goal of preserving the operational space environment binds all space participants with a common purpose."[1105] The first task, then, would be the improvement and centralization of space situational awareness, which serves as an indicator of overall environmental quality.[1106]

There are several ways in which the existing outer space regime is stymied by its failure to adopt an environmental approach. Article 9 of the OST requires state parties to "undertake appropriate international consultations" before engaging in an activity that would "cause potentially harmful interference" with other space activities. This part of the treaty is a general mandate to address the issue of interference, without specific rules, and has been described as "vague and insufficient."[1107] It is unclear whether the creation of space debris falls under the legal rubric of "potentially harmful interference." The lack of mandated consultations by debris-creating space actors suggests that they either do not see debris creation as "potentially harmful," or are simply ignoring their legal responsibility. It is note-worthy that Article 9 requires consultation in the event of "harmful interference with activities of other State Parties." This demonstrates how the collective security approach overlooks harm to the environment. Space debris is not a direct form of interference, so it is easy to pretend that it does not qualify as "harmful"

[1104] Richard DalBello, "Cooperative Management of the Space Environment," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 175.
[1105] Ibid., 176.
[1106] Sadeh, "Spacepower and the Environment," 269.
[1107] United Nations Institute for Disarmament Research, *Security in Space*, xxvii.

because no specific actor is harmed. This view is also evident in the fact that a state is not liable for the "mere presence of orbital debris."[1108]

The applicability of the Liability Convention to the issue of space debris is also uncertain, but generally treated as if there was no connection between the two. The Convention applies absolute liability to space actors that cause harm on Earth, and fault-based liability in the case of harm caused in outer space. As per Article 1, the Liability Convention applies to "space objects" defined as including "component parts of a space object as well as its launch vehicle and parts thereof." All artificial and anthropogenic space debris is a space object, part of a space object, or part of a launch vehicle. Article 8 clarifies that the ownership of outer space objects does not change depending on their location on celestial bodies, in orbit, or returned to Earth. International lawyers have interpreted this to mean "jurisdiction and control of a State over its space objects is permanent."[1109] So the text of the Liability Convention seems to clearly indicate that space debris ought to be understood as owned by the launching and/or registry state, which is therefore liable for any harm caused by it. There is no separate legal definition of "debris."

This interpretation is unlikely to be accepted by the major space actors responsible for almost all of currently orbiting debris: the United States, Russia, and China. There are several ambiguous features of the relevant law that can be used to avoid the costs associated with liability. First is the problem of attribution: it is often difficult or impossible to prove the origin of a particular piece of debris.[1110] Space debris is a problem more akin to ocean acidification than oil dumping; it is hard to keep track of

[1108] Office of Technology Assessment, "Orbiting Debris: A Space Environmental Problem," 9.
[1109] Reynolds and Merges, *Outer Space*, 2008.
[1110] Ibid., 188–89.

individual contributions to the problem. Second, it is difficult to ascertain fault. What if the launch occurred before debris was a known problem? What if the debris was a result of a previous collision? What if the damaged satellite could have but did not maneuver to avoid collision? The Liability Convention provides no answers to these questions.

Active remediation will be required to solve the debris problem, but the existing outer space regime discourages investment in the development or deployment of the necessary technology. In a 2011 article in *Space Policy* Brian Weeden provides a useful overview of the legal and political challenges associated with any future debris remediation project. Assuming that a remediation technique is demonstrated to work, its owner or the international community will have to make decisions about which debris to remove. There exists no consensus about which debris to prioritize, and there are several potential criteria (including ease of maneuver, size of object, and location in heavily trafficked orbits). Because there is no legal distinction between functional and non-functional space objects, there may be disputes about whether a non-operational satellite is subject to removal. The owner may see the defunct object as a useful placeholder, a future 'fixer-upper,' or a stockpile of valuable intellectual property. Article 8 of OST explicitly provides for continuous jurisdiction and ownership over space objects, which creates a legal barrier to non-targeted debris removal.[1111] And because debris removal technology will certainly be dual use, investment and operations may cause distrust within the space community. Remediation techniques that target defunct satellites are exactly an ASAT capability. And once removal is underway, there is a chance that

[1111] Michael Listner, "Taking Salvage in Outer Space from Fiction to Fact," *The Space Review*, March 20, 2017.

operations may cause additional unintentional hazards for space activity, such as accidental collision.[1112]

The problem of space debris was unknown and unanticipated at the time of OST regime formation. The early dominance of the high seas analogy did not encourage critical reflection on the possibility of environmental harm through pollution. Space actors, international lawyers, and the general public believed that space was a vast, even limitless, environment. The importance of effective distance and concentration of valuable orbital pathways was generally neglected in considerations of space security. The resulting collective security approach embedded within the regime makes it difficult for space debris mitigation, liability, or remediation to fit within existing institutional forms. An environmental approach to space security is the best way to confront the problem of space debris, because it creates a specific and coherent collective interest, and sidesteps attribution issues.

Commercialization

Like many international institutions, the OST regime is fundamentally state-centric. It was created during a period in which state governments and/or militaries were the only space actors. The recent emergence of private space actors creates complications for the existing OST regime. In particular, the increase in space activity by private actors raises questions about their rights and duties in outer space. The basic problem is that the legal regime for private and commercial space enterprises is unclear, and subject to competing interpretations. A review of the relevant regime provisions, and a survey of private space activities, will set the stage for an analysis of the sources of this problem.

[1112] Weeden, "Overview of the Legal and Policy Challenges of Orbital Debris Removal."

The original regime architects did not intend for the OST, a "Treaty on Principles," to be a permanent code governing all aspects of space activity. The Treaty was just a modest affirmation of principles, offered in the annex of UNGA Resolution 2222. One of these principles defines the relationship between member states and space actors, which is very similar to the flagging system present on the high seas.[1113] Article 6 of OST requires the "authorization and continuing supervision" of all space actors by states, who are responsible for enforcing the regulatory regime. Article 8 adds that states retain control and jurisdiction over their space objects regardless of their location. The OST therefore prohibits private and unregulated activity in space.[1114] The Liability and Registration Conventions clarify which state has legal responsibility for space launches and objects. Article 1 of the Liability Convention defines the "launching state" as a state that "launches or procures the launching of a space object" and/or the state "from whose territory or facility a space object is launched." Article 1 of the Registration Convention adds the concept of a "state of registry," which is the launching state on whose register the space object is listed. Two UNGA Resolutions – 59/115 and 62/101 – add some detail to these concepts, but basically implore states to clarify their own practices regarding jurisdiction, registration, and ownership.

The commercialization of outer space activities was not on the horizon of feasibility when OST was negotiated. Private firms participated in the 1960s as contractors, and in the 1970s as providers of enhanced remote sensing data.[1115] In the 1980s, deregulation of communications satellites in many countries increased the involvement of private firms, including growing competition in the payload and launch

[1113] Peterson, *International Regimes for the Final Frontier*, 91.
[1114] Reynolds and Merges, *Outer Space*, 74.
[1115] Peterson, *International Regimes for the Final Frontier*, 16.

sectors.[1116] The persistently high cost of launch technology has historically kept the number of space users low, but recent advances in computing, communication, and manufacturing have decreased the cost of satellites.[1117] Today, multinational companies, non-governmental organizations, and venture capitalists are important space actors.[1118] Private investment in space now outstrips government investment, and the commercial sector is creating new markets without the direct assistance of governments.[1119] While early space actors were immediately concerned with the survival and structural integrity of space objects, space enthusiasts now speak of achieving "maximum benefit for mankind" through "[opening] up outer space for development."[1120] Cross-national collaborations are also more common; "traditional distinctions between public and private, and domestic and international are blurring."[1121] There are currently four main sectors of the commercial space industry: satellites services, satellite manufacturing, launch services, and ground equipment. The development of small satellites boosts both satellite manufacturing and satellite and launch services, because it "promises to increase payload versatility while reducing manufacturing and launch costs"[1122]

The last decade has been marked by an "increased acceptance of high-risk commercial space business ventures."[1123] American 'space entrepreneurs' advocate for private enterprise to take the lead on pioneering new uses for space, and a handful of

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[1116] Ibid., 236.
[1117] Baiocchi and Welser, "The Democratization of Space."
[1118] Moltz, *The Politics of Space Security*, 27.
[1119] Joseph Fuller et al., "The Commercial Space Industry: A Critical Spacepower Consideration," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 121.
[1120] Vladimir Putkov, "Sputnik and Russia's Outer Space Activities," in *Celebrating the Space Age: 50 Years of Space Technology, 40 Years of the Outer Space Treaty ; Conference Report, 2 - 3 April 2007*, ed. Vereinte Nationen, UNIDIR, 2007,4 (Geneva: UNIDIR, United Nations Institute for Disarmament Research, 2007), 37.; Listner, "Taking Salvage in Outer Space from Fiction to Fact."
[1121] United Nations Institute for Disarmament Research, *Security in Space*, xxvii.
[1122] Fuller et al., "The Commercial Space Industry: A Critical Spacepower Consideration," 109.
[1123] Ibid., 118.

‘tech’ billionaires have formed companies to actualize this goal.[1124] Planetary Resources Inc., Deep Space Industries, and the Shackleton Energy Company all have plans for commercial mining, either on asteroids or the Moon. Space X, Blue Origin, and others are investing in reusable launch systems to reduce cost.[1125] The Golden Spike Company and Moon Express are focused on the prospect of tourist trips to the moon, although it is Space X that recently announced plans for a 2018 tourist trip around the moon.[1126] Other potential commercial space applications include space business parks, fast global package delivery, movie studios, orbital transfer infrastructures, and energy and material support to the International Space Station or potential lunar bases.[1127] Commercial space activities are understood as a “largely unexplored and untapped frontier.”[1128]

The multiplication of a large number of small, private space actors creates a risk that these new users will “operate independent [sic] of national policies.”[1129] Commercialization of space activities presents two basic challenges for the outer space regime: the question of private property, and the possibility of the emergence of a ‘flags of convenience’ system. Because the diffusion of space technology was delayed, and commercial space actors did not operate independently until the 1980s, the outer space regime was not constructed with these uses and users in mind. The basic regime flaw is that OST created a two-layer regulatory system (international-state) for what became three-layer regulation problem (international-state-private). Declaring outer space the ‘province of all mankind’ established a weak *res communis* regime, which explicitly

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1124 Jakhu, Pelton, and Nyampong, *Space Mining and Its Regulation*, 60.
1125 Ibid., 28.
1126 “First Tourist Trip around the Moon Planned for 2018,” *Al Jazeera*, March 1, 2017.
1127 Bekey, “The Long-Term Outlook for Commercial Space.”
1128 Fuller et al., “The Commercial Space Industry: A Critical Spacepower Consideration,” 119.
1129 Baiocchi and Welser, “The Democratization of Space.”

excludes sovereign appropriation, but is unclear on the question of private property. The regime also assumes, but does not establish, a meaningful and substantive connection between states and private actors, as evidenced by the multiple criteria through which an actor can choose the state with which it registers.

Most widely discussed is the question of private property. The prospect of private asteroid and lunar mining raises important legal and regulatory issues.[1130] On its face, the principles and rules of the OST regime seem to prohibit private property in space. Article 2 of the OST declares that outer space is "not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means." Some space scholars interpreted this provision to "bar *any* property rights in outer space resources."[1131] In the common law tradition, sovereignty is required for the recognition of private property. But in the civil law tradition, property rights are understood to be independent of sovereignty.[1132] Article 6, which provides for state authorization and supervision, has been described as "the foundation of the de jure and de facto subordination of private interests in extra-terrestrial commercial development."[1133] Although the view that the OST regime prohibits private property is "widely prevalent," these interpretations of the treaty are increasingly challenged.[1134] Actors on both sides of the debate have an incentive to resolve it: entrepreneurs and economic nationalists who favor private property want to redress the legal ambiguity that discourages investment, and OST traditionalists who oppose private property want to stem the tide of

[1130] Jakhu, Pelton, and Nyampong, *Space Mining and Its Regulation*, 69.
[1131] Reynolds and Merges, *Outer Space*, 82.
[1132] Scott Pace, "Merchant and Guardian Challenges in the Exercise of Spacepower," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 144.
[1133] Dolman, *Astropolitik*, 130.
[1134] Pace, "Merchant and Guardian Challenges in the Exercise of Spacepower," 146.

commercialization before vested interests gain a major foothold in space activities. Because many space resources are non-exhaustible (or functionally non-exhaustible) and non-excludable, there are a wide variety of potential allocation schemes.[1135]

The Moon Treaty[1136] (1979) offers an answer to this question, but none of the major space powers are party to it. Negotiations over the Moon Treaty were initiated by the United States and Soviet Union in the late 1960s, and the United States proposed the addition of the 'common heritage of mankind' (CHM) principle in 1972.[1137] The fact that many diplomats drew on an analogy with the deep seabed to precisely define CHM "triggered very clear perceptions of interest by all the governments involved."[1138] Article 11 declares that "Neither the surface nor the subsurface of the moon [and other celestial bodies]…shall become the property of any state, international, inter-governmental or non-governmental organization, national organization or non-governmental entity or of any natural person." By ruling out all these possible forms of ownership, the Moon as 'common heritage' must be understood as requiring an equal benefit arrangement.[1139]

After the initial proposal of the Moon Treaty, the US perception of its own interests regarding celestial bodies began a multi-decadal shift. US ratification was blocked by a coalition of industry and space activists, including the L5 society, a group that lobbies for space colonization.[1140] A minority of legal commentators argues that the Moon Treaty actually justifies private exploitation, by describing only 'in place' resources as 'common heritage,' leaving the door open for removal and appropriation.[1141]

1135 Reynolds and Merges, *Outer Space*, 155–56.
1136 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies
1137 Peterson, "The Use of Analogies in Developing Outer Space Law," 261, 264.
1138 Ibid., 262.
1139 Dolman, *Astropolitik*, 133.
1140 Reynolds and Merges, *Outer Space*, 9, 22.
1141 Ibid., 111–13, 129, 134.

And indeed, a hypothetical 'Moon Authority' – like the actual International Seabed Authority – could license exploitation by private actors. But most interested parties view rejection of the Moon Treaty as crucial to "the opportunities and prospects for private enterprise development."[1142] Although at least one space lawyer asserts, "the Moon Treaty is very much alive," its low number of state parties suggests otherwise.[1143]

The United States has recently taken the position that commercial space activity can involve the creation of private property. From the 1980s to the 2000s, the US government position was ambiguous and sent a "confused set of signals" about its support or discouragement of commercial space activity.[1144] These uncoordinated signals came from multiple federal agencies, and were sometimes inadvertent. But recently US policy has shifted strongly in favor of private space activity. The 2015 Commercial Space Launch Competitiveness Act states "A United States Citizen engaged in commercial recovery…shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell."[1145] This legislation is the first piece of US law governing private property in outer space, and some argue that it is invalid because it contradicts the OST. According to both customary international law and the Vienna Convention on the Law of Treaties (to which the United States is a signatory), international treaties take precedence over domestic law.[1146] The Commercial Space Launch Competitiveness Act "carefully skirts this issue" by including a disclaimer that

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[1142] Art Dula, "Free Enterprise and the Proposed Moon Treaty," *Houston Journal of International Law* 2, no. 1 (1979): 3–34.
[1143] Michael Listner, "The Moon Treaty: It Isn't Dead yet," *The Space Review*, March 19, 2017
[1144] Henry R. Hertzfeld, "Commercial Space and Spacepower," in *Toward a Theory of Spacepower*, ed. Charles D. Lutes and Peter L. Hays (National Defense University: Institute for National Strategic Studies, 2011), 87.
[1145] Justin P. Rostoff, "Why the Space Resources Section of Federal Law Is Invalid," *The Space Review*, January 23, 2017,.
[1146] See Articles 26 and 27 of the Vienna Convention on the Law of Treaties

the United States does not assert sovereignty, jurisdiction, or ownership over any celestial body.[1147]

Historically, the United States has played an important role in influencing the formation and interpretation of international treaties. In addition to the 2015 legislation described above, current policy of the United States government is beholden to the concerns of private actors, and seeks to avoid making any regulatory moves that would obstruct their space activities. A pro-business, anti-government ideology prevails in the United States Congress. The current House of Representatives Subcommittee on Space recently rejected the conclusions of an Obama-era report calling for new licensing schemes to comply with OST.[1148] The Subcommittee's Chair, Senator Ted Cruz, is calling for hearings to consider modifying the OST to create a more favorable business climate.[1149] But the US ability to influence the interpretation of OST may be waning. The United States continues to lose market share and technological advantage in outer space, as capabilities and markets become increasingly diffuse.[1150] US satellite manufacturers are also at a disadvantage, because US law treats certain types and components of commercial satellites as munitions. The associated "complicated license processing and long delays" discourage multinational companies from purchasing US sourced satellite hardware.[1151] As a result of decreasing dominance of space activity, the US ability to dictate international space policy, or interpret regime text, by unilateral action or

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[1147] Dominic Basulto, "How Property Rights in Outer Space May Lead to a Scramble to Exploit the Moon's Resources," *The Washington Post*, November 18, 2015.
[1148] Jeff Foust, "House Committee Weighs Lighter Touch to Commercial Space Regulations," *Space News*, March 15, 2017.
[1149] Jeff Foust, "Cruz to Hold Hearing on Updating the Outer Space Treaty," *Space News*, May 17, 2017.
[1150] Fuller et al., "The Commercial Space Industry: A Critical Spacepower Consideration," 122.
[1151] James A. Lewis and Erin Schlather, *Preserving America's Strength in Satellite Technology*, Report of the CSIS Satellite Commission (Washington, D.C.: CSIS Press, 2002), 18–19.

declaration has greatly diminished.[1152] For the foreseeable future, the debate about private property in space will remain unresolved.

A second and rarely recognized emerging challenge to the effectiveness of the OST regime is the potential for 'flags of convenience' and 'ports of convenience.' It is interesting that this possibility has been generally overlooked, given the predominance of the high seas metaphor in shaping the outer space regime. The nationalization system, whereby every space actor operates under the authority and jurisdiction of a particular state (OST Article 6), is a way to solve the risks associated with 'open access' by bringing all users under a form of sovereign control.[1153] But because leadership in commercial space activity provides a form of international power, states have an incentive to attract launch customers. Austria, for example, passed a domestic space law in 2011 designed to attract satellite operators "who may see Austria's legal, political, and business environment as a favorable one."[1154] India, worried about commercial space competitiveness with China, is seeking to increase foreign investment.[1155] The combination of high launch costs and national competition creates a risk of regulatory 'race to the bottom' dynamics for the purpose of attracting investment from private space companies.

The OST regime enables this situation. There is no international agreement that deals with launch services, and no prohibition on space actors choosing the launching state that best suits their interests.[1156] There is a reasonable risk that space actors,

[1152] Hertzfeld, "Commercial Space and Spacepower," 81.
[1153] John Vogler, "Global Commons Revisited," *Global Policy* 3, no. 1 (February 2012): 62.
[1154] Listner, "The Moon Treaty: It Isn't Dead yet."
[1155] Zakir Merchant and Aayush Misra, "Enact Regulatory Framework to Tap the Potential of Space Launch Market," *Business Standard*, March 23, 2017.
[1156] Reynolds and Merges, *Outer Space*, 253.

especially private companies, will choose to launch in countries that are non-members of various outer space treaties. It is even possible that those wishing to avoid regulations could launch from platforms in international waters.[1157] UNGA Resolution 68/74 recommends the development of national regulatory frameworks through legislation. Non-uniform national legislation, in addition to inconsistent ratification of regime instruments, creates unevenness in the international regulatory landscape. There are many possible regulations that private and commercial actors might seek to avoid. These might include, for example, national legislation that requires private space actors to provide resources to fulfill the obligations of the Rescue Agreement. The Rescue Agreement was always understood to need updating once spaceflight became commercial, but it remains an agreement among state parties.[1158] Domestic enforcement of Registration and Liability Convention mandates could also be uneven, and encourage the development of a 'flags of convenience' system for space that weakens the overall enforcement and effectiveness of the outer space regime.

Asteroid deflection

None of the domain analogies drawn upon during the formation of the outer space regime would have been capable of capturing the catastrophic, even existential, risk of collision with another celestial body. The outer space regime does nothing to redress the risk of an asteroid or other near Earth object (NEO) colliding with the Earth. Collision is now generally understood to be inevitable, but this realization emerged after the core elements of the OST regime were negotiated. The first asteroids and comets were discovered in the 19th century, and the first NEO was discovered in 1932, but their

[1157] Jeffrey Marlow, "Rogue Actors and the Coming Space Law Crisis," *Discover*, January 25, 2017.
[1158] Peterson, *International Regimes for the Final Frontier*, 87.

distance and trajectory made them non-threatening to the Earth. Astronomers in the 1980s began to realize that NEOs were numerous, and many came "uncomfortably close to Earth."[1159]

Existing knowledge of the NEO threat suggests that all space and non-space actors have an interest in NEO detection and deflection. The risk is non-negligible: there is a roughly 1-in-1000 chance that an asteroid greater than 200 meters in diameter will strike the Earth this century. The mostly likely location, due to its size, is the Pacific Ocean. In this scenario, large tsunamis may swamp coastal megalopolises in Asia and/or the Americas (depending on the location of the strike).[1160] If the NEO struck a continent instead, the follow on effects from injecting particles into the atmosphere, fires, or induced seismic activity could be severe. Humanity has a clear, definite collective interest in preparing for the detection and diversion of these scenarios: "An asteroid or comet is the only natural disaster that can wipe out human society and the only natural disaster that human society can prevent."[1161] And because the development and deployment of deflection techniques requires a long lead-time, starting now is imperative to avoid the risk of asteroid collision.[1162] But the shared vulnerability of NEO collision has a unique feature than obstructs collective interest formation; unlike most natural disasters, "cosmic hazards are unusual in that they are not spatially selective…any point on the planet appears to have a similar chance of being struck."[1163] This randomness makes the threat

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[1159] Peebles, *Asteroids: A History*, 77.

[1160] Harold D. Foster, "Disaster Planning for Cosmic Impacts: Progress and Weaknesses," in *Comet/Asteroid Impacts and Human Society: An Interdisciplinary Approach*, ed. Peter T. Bobrowsky and H. Rickman, 1st ed (Berlin ; New York: Springer, 2007), 455.

[1161] Peebles, *Asteroids: A History*, 236.

[1162] Joseph Packer, Jessica A. Kurr, and Adam Abelkop, "The Policy Trajectory of United States Asteroid Deflection Planning," *Timely Interventions: A Translational Journal of Public Policy Debate* 1, no. 1 (2013): 7.

[1163] Foster, "Disaster Planning for Cosmic Impacts: Progress and Weaknesses," 454.

seem diffuse, when it is actually very acute in the places that are struck, with reverberating consequences that damage surrounding regions. And because the benefits of asteroid detection and deflection are (probably, hopefully) non-excludable, no single state is willing to invest substantial resources in this public good.

There is limited activity underway towards this end. Companies hoping to mine asteroids, like Planetary Resources Inc., are actively pursuing asteroid identification and tracking. But these companies are mapping the solar system in search of NEOs with different qualities, and may have commercial reasons to withhold the information they collect. Arthur C. Clarke first introduced the idea of a 'Safeguard Survey' in 1973, and a NASA-sponsored project of the same name was set up in the early 1990s.[1164] But existing efforts are under-funded and insufficient, and humanity is currently in a situation where "a highly dangerous near-Earth-object could remain undetected until all chance of altering its course has passed."[1165] The barrier to sufficient mapping of the cosmos is political and financial, not technological.[1166]

Current technological feasibility is less certain in the area of deflection. From numerous studies and concepts, three "apparently realistic methods" have emerged: kinetic impact, gravity tractor, and blast deflection.[1167] NASA's initial default strategy for asteroid deflection was a nuclear explosion (blast deflection). [1168] But NASA's current "Asteroid Impact and Deflection Assessment" mission is an international collaboration

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1164 Ibid., 459.
1165 Ibid., 460.
1166 Giovanni B. Valsecchi, "Evaluating the Risk of Impacts and the Efficiency of Risk Reduction," in *Comet/Asteroid Impacts and Human Society: An Interdisciplinary Approach*, ed. Peter T. Bobrowsky and H. Rickman, 1st ed (Berlin ; New York: Springer, 2007), 209.
1167 Patrick Michel, Francesca E. DeMeo, and William F. Bottke, eds., *Asteroids IV*, The University of Arizona Space Science Series (Tucson : Houston: The University of Arizona Press ; Lunar and Planetary Institute, 2015), 842.
1168 Packer, Kurr, and Abelkop, "The Policy Trajectory of United States Asteroid Deflection Planning," 3.

with the goal of demonstrating a kinetic impact on a small asteroid in 2022. No deflection technique or technology has even achieved the proto-type phase.

Because the outer space regime requires neither investment in the identification and tracking of NEOs nor facilitates coordination in deflection strategies, it fails to achieve security from outer space threats to Earth. But the regime also presents several legal issues for any space actor(s) who voluntarily pursues security from NEOs. These legal issues may deter attempts at developing a planetary defense, because they are sure to bring "political and academic condemnation, tabloid stories of cover-ups and failures, and lawsuits attempting to stop it."[1169] The pursuit of nuclear deflection strategies would arguably violate several parts of the outer space regime. The 1963 Limited Test Ban Treaty prohibits "causing, encouraging, or in any way participating in…any other nuclear explosion." This would ban both nuclear explosions as a technique of changing the orbital path of an NEO and nuclear explosion as a means of breaking up an asteroid.[1170] OST prohibits the stationing of any weapons of mass destruction in outer space, but "celestial objects that provide little warning time…could only be deflected if a system is already developed and stationed in outer space."[1171] Another major issue is liability. It is possible that, in the course of a deflection attempt, a country could inadvertently create a different type of risk. For example, blowing up an asteroid with a nuclear weapon may turn one large object into hundreds of small radioactive objects that might still strike the Earth. Another scenario involves an incremental conventional deflection technique like a 'gravity tractor.' It may occur that this technique moves the NEO, but not enough.

[1169] Peebles, *Asteroids: A History*, 234.
[1170] Reynolds and Merges, *Outer Space*, 61.
[1171] Packer, Kurr, and Abelkop, "The Policy Trajectory of United States Asteroid Deflection Planning," 5.

Instead of striking country A, the NEO strikes country B.[1172] Under the Liability Convention, any damage to the Earth caused by a space object entails 'absolute liability.' But since the space object that causes the damage – the NEO – is not itself registered or launched by any state, these provisions may not apply in the event of botched deflection.

[1172] Ibid., 6.

Table 24.1. A summary of *(i)* the main secondary hazards that may be triggered by an asteroid impact, *(ii)* the mechanisms or condition by which they can cause harm, *(iii)* the environmental variables which could influence their occurrence, intensity and reach and, *(iv)* the kinds of habitat, land use, settlement and social conditions influencing vulnerability to these hazards (hazards after Avdushkin and Nemchinov 1994; Toon and Zahnle 1994)

Secondary hazard	Dangerous mechanisms	Earth environment variables	Social vulnerability concerns
Dust injections and dispersal	Atmosphere effects: – Cooling – Blocking sunlight – Reduced visibility – Toxicity	*A/L/O*[a] – Stratosphere/troposphere loadings – Inversion layers	– Biotic resources – Crop loss – Food security – Heating buildings – Respiratory health
Water injections	Atmosphere effects: – Troposphere warming – Stratosphere cooling (ice clouds) – Transparency – Chemistry	*O/A* – Regional air mass – Circulation – Latitude – Hemisphere	– Agriculture – Energy supplies – Transportation
NO_x, SO_x injections	Atmosphere effects: – Cooling – Chemistry – Acid rain – Toxicity	*A/O/L* – Bedrock, soils – Vegetation – Land use – Industries	– Agriculture – Water quality – Aquatic life – Lake/river amenities
Fires	– Combustion – Soot (cooling) – Pyrotoxins – Acid rain	*L/A* Land cover: – Natural vegetation – Crops – Built-up – Toxic industries and materials	Natural resources: – Forest/Grasslands – Crop lands – Food security – Water contamination – Respiratory health
Water waves and tsunami	– Impact waves – Long-distance waves – Inundation – Destructive impact – Sedimentation – Contaminant transport	*O* – Water depth – Basin configuration – Coastal configuration – Islands – Estuarine environments	– Coastal occupancy – Fisheries – Maritime trade – Tourism and recreation – Island peoples – Drownings
Geomorphic hazards	– Landslides – Flooding – Sedimentation	*L* – Topography – Drainage systems – Regolith	– Land use – Settlements – Water supply
Induced seismicity	– Earthquakes	*L* – Tectonics	– Macro- and micro-seismic vulnerability
Untimely ('Nuclear) winter'	– Zero or limited photosynthesis – Surface cold – Impaired hydrological cycle	*A/L* – Atmospheric circulation – Hemisphere	– 'Dyings' extinctions? – Food security – Energy supplies – Natural resources

[a] *O* = Oceanic environment constraint/effect; *L* = terrestrial environment constraint/effect; *A* = atmospheric environment constraint/effect.

Figure 22 - Expected impacts of asteroid collision, From Hewitt, Kenneth. "Social Perspectives on Comet/Asteroid Impact (CAI) Hazards: Technocratic Authority and the Geography of Social Vulnerability." In Comet/Asteroid Impacts and Human Society

"All I'm saying is now is the time to develop the technology to deflect an asteroid."

Fig. 3.1. Cartoons are a form of printed popular culture that is sometimes used to express a particular viewpoint on a current issue through the use of visual humor, as in the case of this 1998 cartoon advocating development of a technology for asteroid deflection. Used with permission, © The New Yorker Collection 1998 Frank Cotham from *cartoonbank.com*. All Rights Reserved

Figure 23 - Folly of ignoring asteroid risk, From Hartwell, William T. "The Sky on the Ground: Celestial Objects and Events in Archaeology and Popular Culture." In Comet/Asteroid Impacts and Human Society

Regime Proposals

The outer space regime has failed to solve the problems of militarization, commercialization, space debris, and asteroid deflection. Because outer space is politically constructed as a global commons, many proposals for augmenting the regime focus on privatization schemes.[1173] The explanation of the current regime's failure to serve interests and avoid problems elaborated here suggests a different direction for regime augmentation. The basic problem with the outer space regime is that it was built too fast, and then too slow. The OST and follow-on agreements are founded upon 1960s and 1970s knowledge of the space environment and what humans would be able to do there. This incomplete knowledge resulted in several distortions. In terms of practices, negotiators focused more on space vehicles than satellites and appropriation instead of exploitation. They did not anticipate the potential of technological diffusion to a large number of private actors. Interests were, in general, poorly formed. While a broader notion of 'collective security' did emerge and drive the regime, the resulting treaties are poorly equipped to deal with issues of environmental and existential insecurity. Shared problems were therefore understood as historically familiar state-to-state competition and conflict, as opposed to the quality and character of environment that contains primarily spatial extension resources.

The chances are low that negotiators in the late 1960s and early 1970s could have designed a regime that remains effective today. Even if they had better maps and theories about the orbital environment, planning for technological change would require

[1173] Pace, "Merchant and Guardian Challenges in the Exercise of Spacepower," 147; Reynolds and Merges, *Outer Space*, 173, 176.

something close to omniscient technological forecasting. Technology changes at an unsteady pace in uncertain directions, which makes both its composition and distribution difficult to predict. But the OST was not designed with flexibility or adaptation in mind, and the amendment process is moribund. While this persistence without augmentation or reform could be understood as laudable durability, from another perspective "the OST suffers from neglect."[1174] The early period of vigorous and comprehensive regime formation has been replaced with obstructionism and apathy. This situation can be understood as a 'lag' between the shared problems and collective interests that have emerged over the last several decades, and the institutions tasked with and designed to deal with them.

Because effective distance and orbital dynamics make EOS small and integral, the increased density of space activities forces an either/or choice. Commercial development cannot occur sustainably in the absence of a debris control regime, and with the continuing possibility of ASATs. A space traffic control regime, suggested elsewhere, could serve three sets of interests: commercialization, debris control, and ASAT prohibition.[1175] The best version of this regime augmentation would incorporate the lessons generated from the evaluation and criticism of the existing regime provided here.

The choice of "shared conceptual framework" affects calculations of interests and characterizations of problems, and serves as a focal point for bargaining and persuasion.[1176] Political decision makers continue to reify the state-centric framework embedded in the outer space regime, which distorts the identification of interests and

[1174] Ambassador Paul Meyer, Space security and the 50th anniversary of the Outer Space Treaty, interview by Jessica West, Spring 2017.
[1175] Theresa Hitchens, "Debris, Traffic Management, and Weaponization: Opportunities for and Challenges to Cooperation in Space," *The Brown Journal of World Affairs* 14, no. 1 (Fall 2007): 173–86.
[1176] Peterson, "The Use of Analogies in Developing Outer Space Law," 247, 266.

problems.[1177] The result is sovereignty-centric systems of registration, liability, and ownership that complicate the effective regulation of space activities. In contrast, the materialist geopolitical prescription for reforming the outer space regime emphasizes the limits of analogical reasoning and the potential dysfunction of constructed political geographies. Instead of viewing outer space as a global commons just like the high seas or atmosphere, it should be approached as a unique planetary domain with increasingly understood and technologically accessed material features. The geophysical and technological contours of issues in outer space determine which solution sets are most viable. The framework of environmental security has the advantage of encompassing the entire volume of orbital space, while focusing on the patterns of orbital pathways and orbital decay. The spatial approach to delimitation sidesteps the distinctiveness issues that plague the prevailing functional approach.

[1177] Frank Biermann, *Earth System Governance: World Poltics in the Anthropocene* (Cambride, MA: MIT Press, 2015), 9.

Conclusion: Planetary Geopolitics, the Territorial State System, and Regime Design

In one sense, it is hard to understand why humankind has been unable to effectively manage shared planetary domains. The 'long peace' after World War II created sweeping opportunities for international cooperation, despite the antagonisms of the Cold War. In the last few decades, technological innovation has reached qualitatively new heights in terms of computing, sensing, and surveillance. Earth system scientists have, through coordinated data collection and theory building, refined and brought into focus a picture of dynamic planetary spaces that is more detailed and accurate than ever before. It seems that humankind, and especially governments, have in the 21st century all the tools and models required for modern scientific management of shared planetary domains. Yet even with the information, the capability, and the political opportunity, global commons regimes (GCRs) for the ocean and outer space remain generally ineffective at achieving their goals. The geopolitical approach taken here offers part of the explanation: regime builders have historically pursued ill-suited territorial approaches, naturalized status quo technological systems, and embedded snapshot images of the domains that regimes are tasked with managing. In other words, existing regime designs have created a dysfunctional relationship with the ever-changing material context.

This chapter considers the implications of the overall argument about GCR ineffectiveness for larger questions and broader debates about the relationship between the territorial state system and world order building. In general, the findings of previous chapters suggest that incremental reform and minor modification of the state system will be insufficient for confronting contemporary problems in the ocean and outer space. The first half of this chapter synthesizes the overarching critique of status quo approaches to global governance in non-terrestrial spaces, by focusing on a set of design flaws in historical and contemporary GCRs. While these findings are not dispositive, they make an important contribution to the larger conversation about human survival and prosperity in the Anthropocene.

These criticisms also point to prescriptions for regime design, which this concluding chapter outlines in general terms. Although the "contours, nature, and scope" of emerging and future problems are "unprecedented and partially unpredictable," scholars of global environmental governance have a normative obligation to generate guidance for creating regimes that can be both durable and effective.[1178] The history of failures in global commons governance suggests the need for a new political paradigm, which will require "creative and architectonic theorizing" on the part of scholars. The application of geopolitical theory to GCRs is part of a larger effort to "rethink, reconfigure, and reemploy the basic conceptual components of political theory and practice" for the purpose of innovating regime theory as applied to non-terrestrial spaces.[1179] In drawing conclusions about effective regime design, it forwards proposals for "appropriate adjustment" in existing governance architectures.[1180]

[1178] Frank Biermann, *Earth System Governance: World Poltics in the Anthropocene* (Cambride, MA: MIT Press, 2015), 177.
[1179] Daniel Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities," in *The Greening of Sovereignty in World Politics*, ed. Karen T. Litfin (Cambridge, Mass: The MIT Press, 1998), 300.
[1180] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 208.

From the historical case studies, several general inferences can be made about the conditions of effective non-terrestrial governance in the Anthropocene. Because each non-terrestrial domain is unique, it is difficult to make specific but generalizable prescriptions about rules, norms, and decision-making procedures. Instead, this chapter outlines a set of design principles, a strategy that facilitates the generation of rules and norms that are "relevant and useful in a diversity of contexts."[1181] In general, diplomats and policymakers are not thinking and planning at the appropriate spatial and temporal scales. They place too much faith in technology, and assign too little importance to scientific knowledge production. As a result, they tend to build regimes that are fragmented, brittle, and outmoded.

The cases of the ocean and outer space demonstrate that state actors have failed to take the insights of contemporary environmentalism seriously enough. Environmental goals are overshadowed by "so-called high politics issues" like security and economic growth, which dominate the policy agenda.[1182] Economic growth "remains the lodestar of most politicians."[1183] The ocean governance regime in particular is "subject to this over-riding political-economic regime focused on growth and sheer volume."[1184] The application of new environmentalist understandings about nature and environmental change would radically alter the priorities, assumptions, and directives of GCRs. In regards to the global commons, environmental activism "combines universalistic moral

[1181] Erling Berge and Frank van Laerhoven, "Editorial: Governing the Commons for Two Decades: A Complex Story," *International Journal of the Commons* 5, no. 2 (August 2011): 163.
[1182] Paul Kevin Wapner, *Living through the End of Nature: The Future of American Environmentalism* (Cambridge, Mass.: MIT Press, 2010), 11.; John Vogler, *The Global Commons: Environmental and Technological Governance*, 2nd ed (Chichester, West Sussex, England ; New York: Wiley, 2000), 202.
[1183] Vogler, *The Global Commons*, 203.
[1184] Rafaella Lobo and Peter J. Jacques, "SOFIA'S Choices: Discourses, Values, and Norms of the World Ocean Regime," *Marine Policy* 78 (April 2017): 32.

concern with a conception of a collective human interest."[1185] Several examples illustrate the vast gap between environmentalist proposals and status quo governance architectures. John Terbough advocates general restraint in access and exploitation, and wholesale public embrace of science.[1186] Daniel Botkin calls for a rejection of steady-state conceptions of goals (like 'maximum sustainable yield'), in favor of focusing on the achievement of rates of change that facilitate adaptation.[1187] Ursula Heise proposes a form of environmental world citizenship, where we 'lean in' to de-territorialization and globalization in order to dissolve territory-based affiliations.[1188] Daniel Deudney calls for wholesale ideational and institutional change, including the recognition of inter-generational sovereign publics, a federal-republican Earth Constitution, and Earth nationalism.[1189] While there is diversity among these proposals, three common themes stand out: prioritizing scientific understandings, dissolving and replacing national conceptions of interest, and creating new forms of centralized coordination, decision-making, and management. This project connects a criticism of existing regimes with modified versions of environmentalist prescriptions.

Underlying these proposals is an integrated and sophisticated understanding of the planet as a set of interdependent systems and processes. The natural sciences have introduced a "paradigmatic shift toward an earth system perspective" that has yet to truly

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[1185] Vogler, *The Global Commons*, 201.
[1186] John Terbough, "Can Our Species Escape Destruction?," *Atlantic Monthly*, October 13, 2011.
[1187] Daniel B. Botkin, *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered, from Climate Change to Species Extinction, How Life Persists in an Ever-Changing World* (Oxford ; New York: Oxford University Press, 2012); Terbough, "Can Our Species Escape Destruction?"
[1188] Ursula K. Heise, *Sense of Place and Sense of Planet: The Environmental Imagination of the Global* (Oxford : New York: Oxford University Press, 2008).
[1189] Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities."

take hold in the governance of non-terrestrial spaces.[1190] This unified perspective is evident in labels and categories like 'Earth system science' and 'biogeochemistry.'[1191] The Earth-centric paradigm involves concepts of global environmental change, earth system analysis, sustainability science, and resilience theory. Most critically, this new paradigm implies that the Earth itself is the appropriate unit of analysis; "Boundaries between local and global are systematically broken down in both theory and research practice."[1192] The Earth-centric paradigm presents an interesting challenge to the study of global commons regimes, which tends to reify the institutionalized separation between planetary domains like the ocean, atmosphere, and outer space. A wholesale embrace of the Earth-centric paradigm implies an important and fundamental shift in regime theory and practice. Of course, whether or not this shift occurs depends in large part on the social, political, and psychological obstacles to adopting a fundamentally new approach to global governance. But there is value in entertaining alternative perspectives, which "allows us to see the world afresh, revealing patterns and connections that may be obscured in our standard worldview."[1193]

The role of the social sciences in this new Earth-centric paradigm is poorly defined, but the geopolitical approach connects its insights with the history of global commons regimes. Planetary geopolitics generates a critique of existing regimes, and prescriptions for regime augmentation, with reference to the Earth system perspective. This includes observing technological growth as a whole, aside from state interests, and

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[1190] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 16.
[1191] Earth System Sciences Committee NASA Advisory Council, *Earth System Science Overview : A Program for Global Change* (Washington, D.C: National Aeronautics and Space Administration, 1986); Terbough, "Can Our Species Escape Destruction?"
[1192] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 21.
[1193] Martin W. Lewis, "Dividing the Ocean Sea," *The Geographical Review* 89, no. 2 (April 1999): 189.

approaching Earth system science as a unified endeavor to uncover and explain globally interconnected geophysical and ecological processes. Earth system science represents an alternative cognitive framework for approaching governance in non-terrestrial domains, and addressing the collective action problems that emerge in the global commons. It also implies the need for drastic shifts in the structure and function of global commons regimes. The regime pathologies identified here point to three fundamental flaws in the design of existing GCRs, from which we can infer three design principles for effective governance.

Design flaws	**Design principles**
Territorial state system	Centralization
Artificial domain divisions	Forecasting and flexibility
Time Horizons	Scientific knowledge production

Global Commons Regimes

Identifying the fundamental problems with existing GCRs is an important pre-requisite to the formulation of solutions, and the construction of more effective regimes. Major reforms and augmentations are often disregarded as politically and practically infeasible. While political and practical obstacles are real and important, it is a mistake to use their existence as a reason to normalize, and even naturalize, the status quo. This section problematizes three consistent features of GCR design, in order to demonstrate the need for new design principles.

Territorial State System

The idea that the territorial state system is at the root of contemporary human problems is relatively common in academic scholarship. This basic critique emerged in the early years of the Cold War, when technological change wrought major changes to international economics and society. Realist John Herz argued that the advent of nuclear weapons made sovereign states obsolete as security providers.[1194] The mathematician John von Neumann thought that effectively dealing with technological progress was impeded by the overly narrow and under organized state system. For him, the state system stymied the safety mechanism of expanding political integration as the scope of technology expands.[1195] Futurist Buckminster Fuller referred to an "utterly obsolete sovereign separateness," which impedes both understanding of the global situation, and effective coordination and cooperation.[1196] The criticism persists in more recent scholarship. Ulrich Beck has provided a sweeping critique of "methodological nationalism," which pervades the work of historians specifically, and social scientists more generally.[1197] Paul Harris has railed against the "cancer of Westphalia," while Susan Buck notes more mildly "absolute sovereignty is an idea whose time has passed."[1198] Agnew and Muscarà have argued that the conventional account of a "totally territorial" spatial organization of world politics relies on outdated and problematic assumptions about how and where sovereign power functions, the division between domestic and foreign, and the boundaries of society.[1199] Richard Falk has rejected the ethos and praxis of the "old Earth," which he describes as "the primacy of national interests as modified by the priorities of economic globalization."[1200] After the 1972 Stockholm conference,

[1194] John H. Herz, "Rise and Demise of the Territorial State," *World Politics* 9, no. 4 (July 1957): 473–93.
[1195] John von Neumann, "Can We Survive Technology?," *Fortune*, 1955.
[1196] R. Buckminster Fuller, *Operating Manual for Spaceship Earth* ([Carbondale: Southern Illinois University Press, 1969), 31.
[1197] Ulrich Beck and Ciaran Cronin, *The Cosmopolitan Vision*, Reprinted (Cambridge: Polity Press, 2006); David Armitage, *Foundations of Modern International Thought* (Cambridge ; New York: Cambridge University Press, 2013), 17.
[1198] Paul G. Harris, *What's Wrong with Climate Politics and How to Fix It* (Cambridge: Polity Press, 2013).Susan J Buck, *The Global Commons an Introduction* (Washington, D.C.: Island Press, 1998), 28.
[1199] John A. Agnew and Luca Muscarà, *Making Political Geography*, 2. ed (Lanham: Rowman & Littlefield, 2012), 176.
[1200] Richard A Falk, "Scholarship as Citizenship," in *New Earth Politics: Essays from the Anthropocene*, ed. Simon James Nicholson and Sikina Jinnah, Earth System Governance (Cambridge, Massachusetts London, England: The MIT Press, 2016), 99.

Falk concluded that "the global intergovernmental mechanisms of problem solving and policymaking were deficient from the perspective of global public interests due to the primacy of national interests and Western dominated geopolitics."[1201] Clearly, the territorial state system has been recognized as an insufficient organizing framework in the face of global-scale challenges more generally, and global environmental governance specifically.

Despite these Earth-centric criticisms, the territorial state system is deeply embedded within governance of non-terrestrial spaces, where regimes are built upon state-centric ascriptions of cause and consequence, and nationalistic calculations of cost and benefit. Negotiators and diplomats "still operate within the parameters of a nation-state system inherited from the twentieth century."[1202] The GCRs they have constructed are 'international' insofar as they represent the aggregation of and negotiation between national interests, and 'global' in that they cover areas beyond national jurisdiction. But these regimes are not 'planetary' in scope and scale, and GCRs embody a basic myopia about the places they are intended to manage. Regime theory has the same problem as regimes themselves: even theories of global environmental governance remain circumscribed by an "ontological focus on the nation-state system and international diplomacy."[1203] Existing theories of GCRs "share a state-centric myopia" compounded by neglect of broader changes, such as new scientific understandings of Earth systems

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[1201] Ibid., 107.
[1202] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 9.
[1203] Kate O'Neill et al., "Methods and Global Environmental Governance," *Annual Review of Environment and Resources* 38, no. 1 (October 17, 2013): 447.

and processes.[1204] This section describes how GCRs embed and reify the territorial state system, and gestures towards a possible alternative framing.

One conventional view of international regimes is that they modify, constrain, and/or pool state sovereignty in a way that potentially undermines the hegemony of the territorial state system.[1205] Under this view, regimes are the beginning of an alternative to the state system. In contrast, Rolf Lidskog and Göran Sundqvist argue that GCRs actually "reproduce the existing international order in having a state-centered point of departure."[1206] GCRs were produced from an "institutional mold" that relies on borders and states, and which therefore tends to have a poor fit with global environmental problems.[1207] Most obviously, territorialization and sovereign control has been a "typical response" to problems associated with open access to the commons; "the first resort of those concerned with the degradation of the commons is most frequently state regulation."[1208] But even open access designations, like those in orbital space and the 'areas beyond national jurisdiction,' require national flagging for all vehicles, and national systems of regulation and enforcement. And the membership of all GCRs is restricted to state actors, despite the fact that private and commercial actors represent most of the activity in non-terrestrial spaces. Although *res nullius* was generally rejected as a framework for incorporating non-terrestrial spaces into the territorial state system, the alternative of *res communis* still fundamentally affirms the basic categories and practices of territorial states. The more radical alternative of *res publica* was either

[1204] Vogler, *The Global Commons*, 186.
[1205] Buck, *The Global Commons an Introduction*, 28.
[1206] Rolf Lidskog and Göran Sundqvist, "The Role of Science in Environmental Regimes: The Case of LRTAP," *European Journal of International Relations* 8, no. 1 (2002): 80.
[1207] Ken. Conca, *Governing Water: Contentious Transnational Politics and Global Institution Building* (Cambridge, Mass.: MIT Press, 2006), 21, 25.
[1208] Vogler, *The Global Commons*, 62, 15.

rejected out of hand, or aborted in failures such as the modified International Seabed Authority and the Moon Treaty.

The conceptual and political framework of the territorial state system has served humanity poorly in the governance of non-terrestrial spaces. State actors tend to act on a myopic and stunted perspective of interests and problems, elevating parochial, state-specific preferences and agendas that do not serve the collective or long-term interests of humanity as a whole. Thinking about problems through state-centric approaches has obscured the fundamental disruption of planetary systems, and therefore has weakened and diverted the motivation and urgency to redress collective problems and supply public goods. In several cases, scientific consensus about the scope and depth of risks associated with global warming, ocean acidification, and space debris was not sought, recognized, or acknowledged by policymakers. The knowledge was there, but did not easily fit within categories of national interest, which are dominated by domestic calculations of strategic, economic, and military advantage. The problem with state-centered orientations towards non-terrestrial spaces is that they include little incentive to focus on the whole of planetary spaces, and to consider the whole of global interests. Even when scientific consensus is widely disseminated, the state-centric perspective often confounds effective action. Oran Young describes a “tragedy of private property” which could easily be reframed as a ‘tragedy of nationalization.’ The basic message is that nationalization does not necessarily result in incentives for sustainable use, because there are rational reasons for an individual, or an individual state, to liquidate a stock of resources in a short period of time.[1209] Notions of strategic, military, and economic competition between states are a source of such short-term and self-centered incentives.

The establishment and articulation of the territorial state system was an "act of collective human imagination," but that does not mean that it is easy to now escape. Indeed, the emergence of the state system may be "the single most important shift in political consciousness of the last 500 years."[1210] Any attempt to undermine or replace the political geography of the territorial state must reckon with the problem of sovereignty: both its material manifestations (like national militaries, borders, and trade policies) and our psychological attachment to it. Replacing the lens of the territorial state system will require a "revolution in human consciousness" in order to overcome the "particularities of national experience…special interests and bureaucratic rigidities."[1211] The national perspective, like the state system itself, is extremely durable. The primary experience of most humans with the physical environment is immediate and local, and this produces parochial identifications.[1212] When circumscribed experience combines with nationalism and state-level policy-making, the result is narrow interest formation that precludes investment in the idea of a global public. Non-terrestrial spaces may provide a unique opportunity to challenge the psychological and political hegemony of the territorial state system, because they do not contain obvious borders, and because there exist nascent and persuasive alternative images of these domains.

[1209] Oran Young, "Land Use, Environmental Change, and Sustainable Development: The Role of Institutional Diagnostics," *International Journal of the Commons* 1, no. 5 (2011): 166.
[1210] Armitage, *Foundations of Modern International Thought*, 13.
[1211] Falk, "Scholarship as Citizenship," 99.
[1212] Jeffrey D. Straussman, "The Earth as Icon," in *The Limits of Technocratic Politics* (Transaction Publishers, 1978), 60, 68.

We cannot effectively reject the state-centric framework unless a powerful alternative symbol emerges, a new 'whole Earth' image that can usurp existing concepts in the minds of policymakers, diplomats, and the general public. An over-arching conceptual framework is important for political ordering insofar as it "widens enormously our mental panorama" and serves as a "faculty superadded" to our basic perceptions, assisting us in "practically adapting us to a larger environment."[1213] Singular images of the Earth can orient diverse groups towards the same issue, generating patterns in problem perception and interest formation that harmonize collective efforts to avoid shared vulnerability and achieve mutual benefits.

A common perceptual framework is the foundation for a new community of association and affiliation. In John Dewey's terms, it reveals global and planetary publics and turns them into global and planetary communities. The 'whole Earth' images of the early Space Age did not effectively displace the conceptual framework of the modern territorial state system, but a more powerful symbol could. The timing is right for a new shift in global consciousness, as knowledge about and fear of climate change, sea level rise, and ocean acidification becomes increasingly mainstream. The image that prompts a shift must be constructed and refined by scholars of global environmental politics with the problems of governance in the global commons in mind.

The theoretical approach of planetary geopolitics is a step in the right direction. Its reliance on scientific discourse "denies the existence or importance of the national state," because it prioritizes maps and explanations that do not contain or include

[1213] William James, *Some Problems of Philosophy: A Beginning of an Introduction to Philosophy* (New York: Longmans, Green, and Co., 1911), 64.

territorial concepts.[1214] This can be understood as a grand project of place making, which builds connections between spatial extension and human community. Earth system science generates an integrated image of the planet, which implies that the notion of 'place' can be scaled up so that "the whole earth is recognized as a home to the human species."[1215] In this view, the integrated scientific image of the planet is like a cognitive and psychological opportunity to reorient how we perceive, internalize, and respond to understandings of interest and problems. The ultimate aim would be to reformulate regimes from the perspective of the human community on planet Earth. In terms of what these institutions would entail, Frank Biermann's *Earth System Governance* has several specific recommendations for overcoming the territorial state system. These include limiting state autonomy and constructing governance architectures that express and defend "the interests of the international community."[1216] This could be done by altering established concepts in customary international law, to decrease the legal standing of states and increase the legal standing of those acting on behalf of "the interests of the international community as a whole."[1217] Biermann's ultimate aim for this process of institutional change is "a fundamental reconceptualization of the notion of state sovereignty."[1218]

Domain Divisions

The ocean and outer space cases demonstrated the importance of the distinction between the actual material world and the imperfectly constructed picture of it that human users, policymakers, and consumers carry in their heads when making decisions

[1214] Fen Osler Hampson and Judith Reppy, eds., *Earthly Goods: Environmental Change and Social Justice* (Ithaca, N.Y: Cornell University Press, 1996), 7.
[1215] Agnew and Muscarà, *Making Political Geography*, 178.
[1216] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 113.
[1217] Ibid., 116.
[1218] Ibid., 119.

about interacting with that world. Scientific knowledge production has been relatively recent compared to uses of non-terrestrial spaces. But existing GCRs are designed to fit with "perceptions of the extent and linkage between issues."[1219] GCRs have historically embodied a particular pathology: 'frozen ontology,' or the embedding and reification of a progressively outdated understanding of the material features of the ocean, atmosphere and outer space. John Vogler identified this "mismatch between physical systems and issue areas" as a "consistent theme" in GCRs, and argues that it is "obstructive to the solution of commons problems."[1220] Especially important is scientific information about chains of cause and consequence, and the scope and scale of negative effects. In general, outdated information signals outmoded regimes, or those that are not functional relative to their purposes and goals. Vogler explicitly contrasts the "holistic view of the commons" associated with environmentalism and natural science, and the "partial and fragmented" nature of regimes.[1221] Young also notes the difficulty in matching institutional and ecological boundaries; "separating distinct ecosystems is ultimately somewhat arbitrary and may emerge as a barrier."[1222]

Neither Vogler nor Young generate regime design principles from the mismatch between the material context – ecology, geography, technology – and institutional forms. Young prefers to work within existing paradigms and pursue reform rather than renewal or restructuring. Vogler describes GCRs as "hopelessly fragmented." [1223] Although he notes the existence of an argument about congruence between natural and political

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[1219] Vogler, *The Global Commons*, 24.
[1220] Ibid.
[1221] Ibid.
[1222] Oran R Young, *The Institutional Dimensions of Environmental Change: Fit, Interplay, and Scale* (Cambridge, Mass.: MIT Press, 2002), 59.
[1223] Vogler, *The Global Commons*, 2.

geography, he describes it as "impractical," citing nonspecific "strong" political obstacles.[1224] Of course these obstacles exist, but Vogler seems to imply that they are inevitable, and forever insurmountable. He does not see radical political potential in the "ever more holistic conception" of planetary spaces, processes, systems, and problems.[1225]

Perhaps ironically, it is the military that seems most willing to push in the direction of cross-domain unity for the purposes of planning and acting. Captain Mark Redden (USN) and Colonel Michael Hughes (USAF) argue that thickening domain interrelationships are a product of evolution in military capabilities, as opposed to "the physical attributes of the individual domains."[1226] This is only a partial geopolitical argument for collapsing artificial domain distinctions, because it is based on technological capability alone, and not the material features of planetary environments. But its conclusions are similar in form: Redden and Hughes argue that the military should move beyond "geographic stovepipes" that "[lag] the transformational nature of current opportunities and challenges in the global commons."[1227] The alternative they suggest is a "paradigm shift to a macro perspective" and "holistic approach" that focuses on one "complex, interactive system" instead of distinct domains.[1228]

There is also a political-economic argument to be made for the dissolution of divisions between the non-terrestrial domains. The spatial features of the global economy reach into and across all the global commons. Three examples illustrate the scale of

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1224 Ibid., 178.
1225 Ibid., 2.
1226 Mark E. Redden and Michael P. Hughes, "Global Commons and Domain Interrelationships: Time for a New Conceptual Framework?," Strategic Forum (National Defense University: Institute for National Strategic Studies, 2010), 4.
1227 Ibid., 7.
1228 Ibid., 8.

interconnections. Advanced industrial mining – and the gigantic multinational companies that pursue it – have pushed their interests into the formation of both the ocean and outer space regimes. The dynamics of complex international long-distance fishing economies significantly explain the patterns and persistence of the over-fishing problem. And it is ultimately the fossil fuel economy that drives the problem of climate change, and industrial agriculture that causes marine hypoxia and dead zones. In sum, we cannot expect to solve problems or maximize interest satisfaction in one domain without intervening in another.

Planetary geopolitics entails theoretical thinking on a planetary-scale, which is to say above and beyond and across and within all planetary domains. Earth system science continues to progressively undermine the notion that the ocean, atmosphere, land, and orbital space are best understood as separate and distinct from each other. Global environmental problems also reveal cross-domain interdependence. 'Global warming' is now understood as a set of inter-linked and multi-domain phenomena: climate change, ocean acidification, and sea level rise. Global circulation models reveal "complex interdependence between oceans, poles and atmosphere."[1229] Many ocean problems cannot be resolved without regulation in another domain. Pollution, acidification, and excess heat come from the atmosphere. Plastic detritus and toxic agricultural chemicals come from the land. Autonomous submarine-seeking drones operate under the ocean, on its surface, and in the air. Even orbital space is connected, in that the public goods it can provide have impacts on other parts of the Earth. Satellite-based Earth monitoring already provides important information about the ocean, atmosphere, and land. It could potentially provide much more, as raw observational material for the refinement of

[1229] Vogler, *The Global Commons*, 9.

scientific theories about Earth system processes, and especially planetary problems like climate change and over-fishing. Another public good – dealing with the risk of asteroid collision – also requires action in space for a benefit achieved on Earth. Planetary geopolitics thereby demonstrates that solving collective problems and achieving mutual benefit in global governance requires weakening or eliminating the perceived, but artificial, distinction between the ocean, atmosphere, land, and outer space.

Time Horizons

Interest formation and problem definition are also plagued by the problem of time horizons. More specifically, scientific consensus about future impacts is downplayed, overlooked, and even obstructed in cases where it contradicts parochial interests in continued exploitation. Problems like space debris, ocean acidification, and chemical pollution more generally are diffuse and delayed, and therefore tend to play an under-sized role in negotiations over GCRs. A short-term and narrow perspective on interests and problems is self-defeating, because "addressing environmental problems effectively often requires an informed, long-term perspective."[1230] To the degree that time scale issues have emerged in negotiations, they have been mostly focused on the past. Legal concepts like "state responsibility, international liability, reparation, or compensation" are all tied to the idea that past behavior shapes present obligations. Of course, these concepts are "unlikely to be broadly accepted," in large part because present generations refuse to carry the blame from past generations.[1231] Perhaps more critical for ineffectiveness, however, is the lack of attention to the future, and especially the existence of problems

[1230] Pamela S. Chasek, David Leonard Downie, and Janet Welsh Brown, *Global Environmental Politics*, Sixth edition, Dilemmas in World Politics (Boulder, Colorado: Westview Press, a member of the Perseus Books Group, 2014), 250.
[1231] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 191.

for and interests of future generations. The ocean in particular has been called "the largest biotic and abiotic patrimony for future generations."[1232]

John Dewey's notions of public and community provide the conceptual foundation for this critique of interest formation and problem definition, but the criticism itself contradicts his claims about democratic political forms. Dewey defines the public as "all those who are affected by the indirect consequences of transactions to such an extent that it is deemed necessary to have those consequences systematically cared for."[1233] Daniel Deudney explicitly points out that "material contexts will determine the scope of publics," which change with advancements in technology.[1234] In the case of the ocean and outer space, this "human consequence group" clearly extends to future generations, given the nature and persistence of global environmental challenges.[1235] The central challenge of global governance is to generate communities (self-aware publics) and governance (Dewey refers to "government") that fit the scope of the global public. Deudney argues that the proper basis of global governance is therefore an "intergenerational public."[1236]

Dewey endorses the philosophy and practice of democracy more than its empirical institutional forms. But the idea that democracy protects the popular interest is challenged by the problem of inter-generational publics.[1237] In general, short-term thinking by mercurial citizens and election-focused representatives pervades democracies. There is no institutional representation for future generations of citizens, let

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[1232] Adalberto Vallega, "Ocean Governance in Post-Modern Society: A Geographical Perspective," *Marine Policy* 25 (2001): 406.
[1233] John Dewey, *The Public and Its Problems an Essay in Political Inquiry* (University Park, Pa.: Pennsylvania State University Press, 2012), 48.
[1234] Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities," 310.
[1235] Ibid.
[1236] Ibid., 303.
[1237] Matthew Festenstein, "Dewey's Political Philosophy," ed. Edward N. Zalta, *The Stanford Encyclopedia of Philosophy*, Spring 2014.

alone future generations of humanity writ large. The "time structures" of planetary and political systems are incongruent and out of sync.[1238] For Stephen Gardiner, democracy facilitates the "tyranny of the contemporary" and "inter-generational buck passing," such that current populations have little or no motivation to effectively redress problems that are long term or "backloaded."[1239] Laura Westra argues "the unquestioned acceptance of the primacy of democratic institutions…presents the major obstacle to the prevention of public harms."[1240] For her, the problem is that corporate interests are not challenged or balanced by an "overarching conception of 'the good'," so the democratic aggregation of preferences is "routinely manipulated."[1241] Although neither author uses the language of publics and communities, both argue that democracy routinely fails to recognize the scale and scope of publics (in space and time).

This criticism of unit-level democracy applies equally or more so to the GCRs evaluated here. In many cases, their ineffectiveness is a result of overlooking the true spatial and temporal extent of the global public. Issues like ocean acidification and space debris would loom radically larger in terms of interests and problems if the true community-of-consequence were recognized. Enlarging the time horizon for cost benefit analysis would likely result in more cautious, environment focused approaches to global governance.

[1238] Chasek, Downie, and Brown, *Global Environmental Politics*, 250.
[1239] Stephen Mark. Gardiner, *A Perfect Moral Storm: The Ethical Tragedy of Climate Change* (New York: Oxford University Press, 2011).
[1240] Laura Westra, "Environmental Risks, Rights, and the Failure of Liberal Democracy: Some Possible Remedies," in *Environmental Ethics: Readings in Theory and Application*, ed. Louis P. Pojman and Paul Pojman, 5th ed (Belmont, Calif: Thomson Wadsworth, 2008), 686.
[1241] Ibid., 685.

Building Planetary Regimes

The sources of regime ineffectiveness identified in this project have important implications for improved regime design. The key idea is that the most effective institutions are isomorphic with the material context, across both space and time. Achieving isomorphism is a supreme challenge, because models and political forms borrowed from other regimes are unlikely to match with a unique planetary domain. We cannot rely on analogies or models, or simply scale up institutions that function at more local scales.[1242] The ocean is radically unlike outer space in physical form, so we should not expect functional regimes in these domains to look anything alike. The achievement of an isomorphic regime requires relying on a constantly evolving scientific image of the domain in question. But the arguments about artificial domain division considered above imply that the appropriate scale and scope of the political community, and collective governance, may be the Earth itself.[1243] An isomorphic regime would not reify an artificial, or purely socially constructed, domain distinction. Perfect isomorphism requires perfect information, and is therefore impossible. But a rough or serviceable isomorphism between GCRs and material systems can be achieved. This section considers three design principles for fashioning isomorphic regimes to govern non-terrestrial spaces.

Centralization

There is currently no consensus in the regime theory literature about whether fragmentation in governance architectures is good or bad, but there are many arguments

[1242] Paul C. Stern, "Design Principles for Global Commons: Natural Resources and Emerging Technologies," *International Journal of the Commons* 5, no. 2 (August 2011): 218.

[1243] Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities," 303.

on both sides.[1244] Arguments in favor of fragmentation include the increased speed of negotiation and entry into force of agreements with fewer members.[1245] Reducing membership can also result in “more progressive and far-reaching” agreements.[1246] Fragmentation can make it easier for actors to enter into agreements, and tailor those agreements for specific regions or groups.[1247] However, fragmentation inevitably results in agreements that do not take the interests of the global community into account. This is one reason why most developing countries prefer inclusive multilateral negotiations, which allow them to present a unified, and therefore stronger, position in defense of their interests.[1248]

The stakes of ignoring global public goods and shared vulnerabilities in the global commons are very high. Fragmented regimes are unlikely to be interested in or able to redress space debris, ocean acidification, over-fishing, or asteroid collision. The emergence of Earth system science as a general and unified endeavor tells us something important about global governance: the elimination of stovepipes in the former implies a need to reject stovepipes in the latter. More powerful centralized governance institutions could theoretically address many of the issues and challenges found in non-terrestrial domains. The example of anti-piracy measures during the *Pax Britannica* demonstrates the value of jurisdictional scope and centralized enforcement capacity. An additional capacity is necessary in the Anthropocene: a central institution or organization serving as a clearinghouse for scientific knowledge, such that consensus is formed and disseminated

[1244] Frank Biermann et al., “The Fragmentation of Global Governance Architectures: A Framework for Analysis,” *Global Environmental Politics* 9, no. 4 (November 2009).
[1245] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 86.
[1246] Ibid., 87.
[1247] Ibid., 89–90.
[1248] Ibid., 91.

in a more efficient manner. This function might also expedite the transformation of the global and inter-generational public into a self-aware and politically mobilized community, by providing a forum for an "increasingly intensive consultative process – involving those who deploy and those who are affected" by technology in non-terrestrial domains.[1249] Centralized institutions offer an opportunity to think about the consequences of global technological systems as a whole. The magnitude of the impact of current technologies, and likely future innovations, must be considered as a whole in relation to the Earth systems they operate in and exploit. Because of the interdependence of planetary systems, notions like 'carrying capacity' and 'ecological footprint' are best considered as a whole. This is critical to defining the cost of human use activities at global scales, as the state-specific benefits are already well-known.

The implications of centralization for regime design go beyond the creation of "coordination mechanisms" proposed by Young.[1250] Biermann argues in *Earth System Governance* that we need "global stewardship," which he says is different from "centralized management."[1251] But the specific agenda Biermann lays out very much takes places at the center of global politics. Biermann proposes a "transformation" of the United Nations system in favor of a "reformed global institutional architecture of earth system governance."[1252] The idea is to produce a "much needed overarching institution and decision-making system that coordinates, and hence strengthens" hundreds of distinct agreements.[1253] Integrated governance "may promise a higher effectiveness in terms of

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[1249] Seyom Brown and Larry L. Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," *International Organization* 29, no. 03 (June 1975): 890.
[1250] Young, *The Institutional Dimensions of Environmental Change*, 178.
[1251] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 24.
[1252] Ibid., 210.
[1253] Ibid., 99.

solving the core problems" in what have been historically treated as distinct issue areas.[1254] Biermann outlines several specific institutional blueprints, including for a World Environment Organization, a Global Environmental Assessment Commission, a World Environment Fund, a Trusteeship Council for Areas beyond National Jurisdiction, and a UN Sustainable Development Council. This governance architecture centralizes jurisdiction, capacity, and scientific knowledge production. Biermann also flatly rejects the territorial state system as the appropriate framework for earth system governance. He argues that consensus-based international decision-making leads to 'lowest common denominator' governance architectures, and should be replaced with different types of qualified majority voting and circumscribed state sovereignty.[1255] Although Biermann recognizes that political obstacles and functional challenges obstruct this vision of empowered centralization, he advocates for a "realistic utopianism."[1256]

Deudney's "Global Village Sovereignty" offers several ideas for how to make centralization more realistic, and even possible, by focusing on the identity ties that help generate a community out of a mere public. A requirement for tapping into the strength of national affiliations is a "here feeling" or attachment to place. The emergence of nation-states, some of continental size, has already scaled up the identity affiliations of billions of humans. Deudney points to the "planetary evocation of place" in photographs of the planet from outer space, and also suggests that Gaian Earth religions offer conceptual and normative resources for appreciating the Earth as a shared home.[1257] The centralized

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[1254] Ibid., 86.
[1255] Ibid., 208.
[1256] Ibid., 13.
[1257] Deudney, "Global Village Sovereignty: Intergenerational Sovereign Publics, Federal-Republican Earth Constitutions, and Planetary Identities," 314.

scientific image of the planet, when treated as the appropriate object of governance, can also support the psychological transition to viewing the Earth as a home.

The design principle of centralization undermines reliance on the territorial state system and artificial domain divisions as determinants of the appropriate scope and scale of governance. The institutional blueprint implied by the principle of centralization would require a massive transformation of the existing world political order. Despite the obvious difficulties that realizing such a program entails, it is nevertheless valuable, and even essential, to articulate holistic indictments and formulate transformative architectures. Richard Falk suggests that reorientation away from the fragmented state system "is already latent in the body politic," and that awakening more people to "its urgent necessity" is a crucial step in activating its potential.[1258] Although the construction of centralized governance architectures faces many obstacles, there is reason to believe that the process of centralization may be self-reinforcing, insofar as it creates a new locus for identity and interest formation.

Forecasting and Flexibility

Both Fuller and Biermann understand the issue with global governance as a failure to 'steer' human activities and societies towards positive change. And in a real sense, the project of International Relations is "to gain some control over where we are going."[1259] The concept of steering implies both durability and change: a vehicle still exists despite traversing spatial distance. Effective steering, and effective governance, requires a balance between durability and flexibility. The ideal is a permanent organization or institution that can confront unfolding complexity and make the on-going

[1258] Falk, "Scholarship as Citizenship," 98.
[1259] Robert W. Cox, "The Point Is Not Just to Explain the World but to Change It," in *The Oxford Handbook of International Relations*, ed. Christian Reus-Smit and Duncan Snidal, 2008.

decisions required to adapt to new knowledge and new circumstances.[1260] Maintaining congruence with the material context over time, and responding to an evolving cost-benefit analysis, requires a "secure minimum capacity to adapt."[1261] Yet flexibility is not universally seen as an institutional virtue, even in situations of uncertainty.[1262] And there are many reasons that inflexibility is the norm, including decision-making gridlocks, status quo biases, entrenched powerful interests, and general "institutional arthritis."[1263] Regime inflexibility is a fundamental design flaw that occurs when scientific knowledge and technological capability are treated as if they are unchanging.

Centralization and flexibility are often understood to be competing design principles. Decentralization is associated with adaptation and innovation, because smaller organizations can make changes more quickly, and a larger number of organizations can increase the diversity of institutional forms. It may be true empirically that decentralization correlates with flexibility, but the combination is likely to facilitate the wrong kind of flexibility: 'race to the bottom' dynamics and pursuit of parochial interests to the detriment of collective ones. Centralization can help key adaptation and innovation to a specific catalyst for change: scientific knowledge production. And even if centralization makes flexibility more challenging, it does not make it impossible.

Achieving flexibility and adaptiveness to changing material conditions requires close attentiveness to the leading edges of scientific consensus formation and

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[1260] Vogler, *The Global Commons*, 36.
[1261] Berge and van Laerhoven, "Editorial: Governing the Commons for Two Decades: A Complex Story," 165.
[1262] A. Thompson, "Rational Design in Motion: Uncertainty and Flexibility in the Global Climate Regime," *European Journal of International Relations* 16, no. 2 (June 1, 2010): 269–96; Steve Rayner, "Uncomfortable Knowledge: The Social Construction of Ignorance in Science and Environmental Policy Discourses," *Economy and Society* 41, no. 1 (February 2012): 107–25.
[1263] Young, "Land Use, Environmental Change, and Sustainable Development: The Role of Institutional Diagnostics," 166.

technological innovation and diffusion. Young emphasizes the need for "early warning" and "rapid response."[1264] The centralization of scientific knowledge production, synthesis, and dissemination described above can assist in keeping regimes updated in light of changing scientific consensus. The goal is to close the gap between scientific discovery and regime response, to avoid a repeat of the delayed coming-to-terms with space debris, asteroid collision, and sea-level rise, among other examples. Institutionally, this could take many forms, including scientific advisory panels, research clearinghouses, or even technocratic leadership. The institutional goal is to support the collection and dissemination of credible scientific data, and to more closely connect scientific consensus formation with alterations in the rules and norms of GCRs.

Another design feature that could support flexibility and adaptation is technological forecasting. This is already a common endeavor in the worlds of venture capitalism and intellectual property, but rarely appears in discussions of regime theory or regime design. There is, however, growing academic attention to the razors' edge of technological change by scholars of accelerationism, transhumanism, and artificial intelligence. The Institute for Ethics and Emerging Technologies offers an example of comprehensive technological forecasting, but for the purpose of taking advantage of 'techno-progressive' possibilities. In general, the Institute is concerned with exploiting technological opportunity rather than avoiding techno-genic calamities. Techno-forecasting should also be used for the purposes of restraint and regulation. Tracking change in technological composition and distribution would support goal achievement in two ways: by updating our understanding of what technology needs to be regulated, and by identifying and harnessing technology that supports regulatory functions. Tracking

[1264] Young, *The Institutional Dimensions of Environmental Change*, 178.

new technologies of exploitation, access, and surveillance could help regimes identify emerging collective action problems and take advantage of new possibilities for verification. Whether technological forecasting would trigger new mandates for adoption and diffusion, or regulations on design and injunctions against use, depends on whether the emerging technology supports or undermines the goals of the regime. Submarine drones, for example, could be usefully evaluated for their potential to support or undermine the Law of the Sea Treaty, as a way to inform new rules and norms about their deployment and use. Micro-satellites could be evaluated for their likely contribution to space debris. This kind of forecasting and assessment is the best way to 'steer' technological change, instead of sleepwalking into new technological worlds that we only 'choose' in a diffuse and uncoordinated way.

The political obstacles to achieving and maintaining a functional fit with ecological and geophysical planetary systems may be significant. Participants in regime maintenance and augmentation must be active, incentivized, and supported with resources (whether from home governments or elsewhere). Once rules and norms are adjusted to account for prevailing material circumstances – reflecting contemporary scientific consensus and technological capability – the constellation of user interests must be configured to maintain compliance. In some cases, the connection between parochial and collective interests may be sufficient to achieve self-enforcement. In other cases, especially those which concern the interests of future generations, surveillance, enforcement, and adjudication must be capable of identifying and punishing non-compliance. This project does not contain solutions to many of the social and political obstacles to achieving and maintaining a match with the material context. But it does present a set of design principles for achieving effective governance of non-terrestrial spaces. GCRs will be increasingly effective and successful to the degree that they can create institutional capacity for forecasting and flexibility.

Science and Technocracy

Perhaps the single most consistent theme of a geopolitical theory of regimes is the importance of scientific information for the design and function of effective GCRs. Indeed, scientific knowledge production is more important than ever, because in terms of shared problems, "the direction of change is from the visible, concentrated, and well known toward the invisible, diffuse, and unfamiliar."[1265] When there are gaps in knowledge about the scale and character of shared vulnerabilities, this situation opens discursive space for dangerous modernist fictions that enable over-use and over-exploitation.

Design principles for large-scale commons that involve investment in scientific knowledge production have already been introduced. Paul Stern, for example, argues for investment in science to understand the consequences of resource exploitation, and integration of scientific analysis into more general deliberation among stakeholders and monitors.[1266] Biermann envisions a Global Environmental Assessment Commission, which could serve as an "institutionalized early warning voice of the global change research community."[1267] Seyom Brown and Larry Fabian called for "progressive internationalization of capabilities for gathering and assessing information" about non-terrestrial domains in 1975.[1268] And scientists themselves are asserting a more central

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[1265] Mary Graham, *The Morning after Earth Day: Practical Environmental Politics* (Washington, D.C.: Brookings Institution Press, 1999), 5.
[1266] Stern, "Design Principles for Global Commons: Natural Resources and Emerging Technologies."
[1267] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 208.
[1268] Brown and Fabian, "Toward Mutual Accountability in the Nonterrestrial Realms," 889.

role, through activist organizations like the Bulletin of Atomic Scientists, Union of Concerned Scientists, Pugwash, and Physicians for Social Responsibility. Indeed, "pleas for drastic change in global governance are becoming a frequent feature of scientific gatherings."[1269] The involvement of the scientific community in uncovering chains of cause and consequence in the midst of complexity is crucial to regime success. Scientists discover, define, and disseminate information about environmental problems. They also help devise solutions, through efficiency improvements, remediation techniques, and even technological alternatives. Scientists need to keep doing this, but with more intensity and support from governance institutions.

The special authority of scientific knowledge has important implications for regime design possibilities. Regimes can support the legitimacy and credibility of science by maintaining fidelity to the ideals of scientific knowledge production through disciplinary norms, such as blind peer review, data transparency, iterated experiments, and independence from special interests. These norms support the production of less biased and political scientific consensus, but institutional pressure for the provision of definite answers, quotas, and thresholds also must be lifted. Adopting a precautionary approach to access and exploitation can flip the scientific burden of proof in a way that reduces this pressure. In contemporary GCRs, scientists are often asked to identify limits on use under conditions of uncertainty. A precautionary approach could delay authorization of uses until a reasonable certainty is achieved. It may also minimize the risk of abuses of power, by requiring strong evidence to justify new activities.

The case chapters demonstrated the serious value in identifying and reducing scientific uncertainty, or lack of consensus. Uncertainty generates competing

[1269] Biermann, *Earth System Governance: World Poltics in the Anthropocene*, 203.

interpretations of the truth, and "resource users may be tempted to act as if the most optimistic projections…are valid, with the result that there is a pressure for undue risk acceptance."[1270] Scientific knowledge competes on a contested terrain – there are lots of other powerful discourses controlling the conception of a domain, its uses, and possible impacts. Incomplete scientific understanding increases reliance on knowledge generated by users, who have a vested interest in justifying their continued exploitation. This situation is rampant with regard to governance of global fisheries.[1271] Uncertainty may be inevitable in the natural world, but there is value in identifying areas of persistent uncertainty, and areas where consensus knowledge is possible. And reducing uncertainty in the context of independent (legitimate and credible) scientific institutions is critical to strengthen the position of scientific knowledge relative to the narratives and interests of corporations, religious fundamentalists, and other conservatives that often overpower the voice of scientific reason, and the weight of scientific consensus.

The insights of planetary geopolitics could be used to support a strong version of technocracy, or rule by experts (specifically, scientists and engineers). Scientific disciplines already correlate with the divisions and distinctions among natural systems, although these fields are continuously refined. The emergence of unified paradigms like Earth system science and biogeochemistry resulted from growing recognition of the tight interdependence among Earth systems. An ideal match might correlate natural systems, scientific disciplines, and governance institutions. The idea would be to bring the institution closer to the scientific endeavor, as opposed to bringing the science and

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[1270] Stern, "Design Principles for Global Commons: Natural Resources and Emerging Technologies," 223.
[1271] Tom R. Burns and Christian Stöhr, "Power, Knowledge, and Conflict in the Shaping of Commons Governance. The Case of EU Baltic Fisheries," *International Journal of the Commons* 5, no. 2 (September 14, 2011): 175.

scientists into the institutional context. This might facilitate scientific knowledge production, consensus building, and information dissemination among the actors most closely associated with a particular material issue area. Perhaps the regime itself – or regime practitioners, monitors, and enforcers – should be engaged in fieldwork, mapping, modeling, counting, and tracing material phenomena in the area of management. In this technocratic ideal, scientific organization (by discipline, subject matter, and technique) shapes institutional form instead of the territorial state system.

A major challenge with this vision is the need to identify when scientific 'consensus' is actually compromise, or suppressed controversy, as these situations are likely to produce beliefs of fact that are significantly biased by external interests and influence. Scientific consensus provides information that exceeds the "the lay person's range of normal experience," and defines "the scale of problems, the ground for conflicts and the scope of solutions."[1272] It is authoritative and powerful, and therefore self-interested actors have an incentive to frame ideas that benefit them as 'consensus knowledge.' The authority of scientific consensus stems from its status as legitimate, salient, and credible information about non-terrestrial domains.[1273] Yet commons regime theory has under-invested in questions about trust and conflict over information "about the definition, causes, and/or severity of a problem, and the adequate solutions."[1274]

A common criticism of technocracy is that it is anti-democratic, because decision makers are not held accountable to the wishes of the public. This criticism applies more

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[1272] Lidskog and Sundqvist, "The Role of Science in Environmental Regimes: The Case of LRTAP," 77–78.

[1273] Ronald Bruce Mitchell et al., eds., *Global Environmental Assessments: Information and Influence*, Global Environmental Accord Strategies for Sustainability and Institutional Innovation (Cambridge, Mass.: MIT Press, 2006).

[1274] Adam Douglas Henry and Thomas Dietz, "Information, Networks, and the Complexity of Trust in Commons Governance," *International Journal of the Commons* 5, no. 2 (September 14, 2011): 167.

or less depending on the particular governance arrangement, and discipline/sector specific governance may be less offensive to democracy than more oligarchic forms. But the ideal of scientific independence certainly trades off with notions of democratic accountability. Opponents of technocracy argue that what is needed is "more societal control of science," and democratic control of scientific priorities and research.[1275] One major concern with prioritizing democratic accountability is the inability of citizens, or even democratically chosen representatives, to seek out, recognize, and internalize educated and especially long-term conceptions of their own interest. This is one major difference between the design principles for the global commons offered by Paul Stern and those offered here – while he prioritizes accountability to "the wider set of parties affected," I argue that the locus of decision-making should be with experts, not lay people.[1276]

Conclusion

Survival and prosperity in an era of planetary-scale human interaction requires a re-orientation towards governance of the global commons. In short, existing GCRs are not good enough. They are insufficient to achieve sustainable and equitable use of the ocean and outer space, and to avoid the worst catastrophes of over-exploitation, pollution, and disruption of Earth system processes. Although many scholars laud the durability and broad membership of the ocean and outer space regimes, this is a symptom of shifting baselines and lowered expectations. We do not need regimes that last – we need regimes that work. The central flaw of existing GCRs is a mismatch or misfit with the evolving conditions of, and knowledge about, the planetary material context. Regimes lag

[1275] Philip Shabecoff, *Earth Rising: American Environmentalism in the 21st Century* (Washington, D.C: Island Press, 2000), 147.
[1276] Stern, "Design Principles for Global Commons: Natural Resources and Emerging Technologies," 223.

technological change and new scientific knowledge. As a result, they pursue poorly formed and increasingly outdated conceptions of interests and problems.

Regime theorists from diverse schools of International Relations have produced important insights about regime design and effectiveness, but these theories do not tell the full story. A paradigm shift in regime theory that elevates material contextual variables would reveal previously submerged and overlooked factors that have significant explanatory power. The cases examined here offer an initial step in this direction, and demonstrate the utility of adopting a geopolitical approach in the study of global commons regimes. Planetary geopolitics provides a different type of explanation for regime failure, and generates a specific set of design principles for regime augmentation or reconstruction. The ideal GCR is constructed to be maximally isomorphic with the features of the geography, ecology, and technology of the domain of management. This entails a political geography with the appropriate scope and scale, extended time horizons, and attentiveness to the composition and distribution of global technological systems. It requires careful assessment of what we do and do not know about planetary spaces and systems, and investing substantial effort in the creation of scientific maps, theories, and models of non-terrestrial spaces.

The social, political, cultural, and economic obstacles to this ideal vision are significant and robust. Any major changes that close the gap between "horizons of feasibility" and "horizons of necessity" will require a popular social and political mobilization to generate a transformative degree of political will.[1277] Agendas for reformulation must be energized, while inaction and complacency must be problematized. The unwillingness of major actors to entertain more active, expansive,

[1277] Falk, "Scholarship as Citizenship," 98.

and capable regimes should be characterized as a threat to the global human community. There are risks to centralized technocratic administration, but these pale in comparison to the dangers of unchecked global environmental destruction. If even a rough isomorphism between regimes and the planet is impossible to achieve, then a different kind of response is required. Instead of complacency and lowered expectations, the superior option may be radical relinquishment and restraint. But if the human community intends to continue expanding uses in, and extracting benefits from, planetary spaces in the next century, a new path must be forged.

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Curriculum vitae

Elizabeth Mendenhall

Johns Hopkins University

EDUCATION:

2011-2016:	Johns Hopkins University, PhD candidate in Political Science Fields: International Relations (major) and Comparative Politics Thesis: "Shifting Grounds: Scientific and Technological Change and International Regimes for Extra-territorial Spaces" Advisers: Daniel H. Deudney, Margaret E. Keck, Bentley Allan
2011:	Kansas State University, B.A. in Political Science and Philosophy, *summa cum laude*

PUBLICATIONS:

Journals

Published:	"Seamounts as Sites for Governance in the 'Areas Beyond National Jurisdiction," in *SAIS Review of International Affairs*, vol. 36, no. 1 (2016): 61–73.
Under review:	"Fluid Foundations: The Oceanic Opacity Residue, the Transparency Revolution, and Strategic Nuclear Stability," under review at *Journal of Strategic Studies*
Invited to resubmit:	"Teaching Critical Understandings of Realism through Historical War Simulations" (with Tarek Tutunji), at *PS: Political Science & Politics*

Book Chapters

Published:	"New Earths: Assessing Planetary Geographic Concepts," in *Assembling the Planet: The Politics of Globality After 1945*, eds. Rens van Munster and Casper Sylvest, (with Daniel Deudney)
Published:	"Green Earth: The Emergence of Planetary Civilization," in *New Earth Politics*, eds. Simon Nicholson and Sikina Jinnah, (with Daniel Deudney)
Forthcoming:	"The Social Construction of the New Arctic," in *The Social Ecology of the Anthropocene: Continuity and Change in Global Environmental Politics*, eds. Richard Matthew, Kristen Goodrich, Connor Harron, Bemmy Maharramov, Evgenia Nizkorodov

Book Reviews

Forthcoming:	Review of *Consensus and Global Environmental Governance* by Walter F. Baber and Robert V. Bartlett, for *Global Environmental Politics*, forthcoming

FELLOWSHIPS AND AWARDS:

Fellowships

2016: Dean's Teaching Fellowship, Johns Hopkins University
2016: Teaching-as-Research Fellowship, Center for Integration of Research, Teaching and Learning
2016: Joel Steward Ish Fellowship, Johns Hopkins Political Science Department
2014: Charles Latham Pack Fellowship, Johns Hopkins Political Science Department

Academic Awards

2016: Winner, Excellence in Teaching Award, Johns Hopkins University
2011: National Champion, Cross Examination Debate Association (policy debate)
2011: Debater of the Year, Cross Examination Debate Association

TEACHING:

Independent

2017: History of American Environmentalism (lower division), Intersession
2016: Politics of the Ocean (upper division), Fall
2016: History of American Environmentalism (lower division), Intersession

Assistantships

2015: Contemporary International Politics (lower division), Fall
2015: Global Security Politics, Head TA (lower division), Spring
2013: International Politics (lower division), Fall
2013: Global Security Politics (lower division), Spring

Invited Lectures:

2015: "The Discursive Construction of the New Arctic," University of California-Irvine Symposium on Arctic Governance, January
2015: "The Nuclear Political Question," for Global Security Politics (lower division), Spring
2014: "Politics of the Ocean," for Water Politics (upper division), Fall
2014: "Jared Diamond's Guns, Germs, and Steel," for Planetary Geopolitics (upper division), Spring
2013: s"Proliferation, Terrorism, and Arms Control," for International Politics (lower division), Fall
2013: "Asteroid Politics," for Global Security Politics (lower division), Spring

Tutoring

2013-2017: Writing Tutor (shift director), Johns Hopkins Writing Center
2009-2011: Political Science Tutor, Kansas State Student Services for Intercollegiate Athletics

CONFERENCE PARTICIPATION:

Papers Presented

2017: “Modernist Internationalism in the Global Commons,” International Studies Association, February

2017: “Seamounts as Sites for Governance in the ‘Areas Beyond National Jurisdiction,” International Studies Association, February

2016: “Modernist Internationalism in the Global Commons,” American Political Science Association, September

2016: “Ancient and Modern World War Simulations as Supplemental Teaching Tool,” with Tarek Tutunji, International Studies Association, March

2016: “Fluid Foundations: The Oceanic Opacity Residue, the Transparency Revolution, and Strategic Nuclear Stability,” International Studies Association, March

2016: “Green Earth: The Emergence of Planetary Civilization,” International Conference on Environmental, Cultural, Economic and Social Sustainability, January

2015: “The Discursive Construction of the New Arctic,” European Consortium on Political Research, August

2015: “Green Earth: The Emergence of Planetary Civilization,” European Consortium on Political Research, August

2015: “The Influence of Scientific and Technological Change on Global Commons Regimes,” European Consortium on Political Research, August

2015: “Green Earth: The Emergence of Planetary Civilization,” Johns Hopkins Sustainability Roundtable, May

2015: “Harnessing the Hydrosphere: Science, Technology, Ocean Governance,” The New Earth: The Politics of Planetary Places and Spaces, graduate workshop at Johns Hopkins University, April

2014: “The Social Construction of the New Arctic,” International Studies Association, March

2014: “New Earths: Assessing Contemporary Global and Planetary Geographic and Geopolitical Constructs,” *Assembling the Planet* workshop, National Museum, Copenhagen, April

2014: “The New Anarchism: A Geopolitical and Republican Critique,” The ‘Virtues of Anarchy’ Reconsidered workshop, University of Exeter, June

2014: “Ocean Opacity and the Transparency Revolution,” International Studies Association Northeast, November

2013: “Geophysical Transformation and the Nascent Arctic Regime,” International Studies Association Northeast, November

Roundtables

2017: Panelist on “UK Nuclear Weapons: Are they Vulnerable? Are they Independent? Do they Deter? What are they For?” International Studies Association, February

Panels Organized

2016:	"Global Governance in a Changing Ocean," panel for International Studies Association conference, February 2017
2016:	"Modern Internationalisms and New World Orders," panel for International Studies Association conference, February 2017
2015:	"Globalization, Technology, and International Stability," panel for International Studies Association conference, February 2016

Discussant or Chair

2015**:**	"Risk Analysis in the Arctic – Economic Development and Environmental Governance," European Consortium on Political Research conference, co-chair, August
2014**:**	"Arms Control and Non-Proliferation," panel at International Studies Association Northeast, discussant, November
2014:	"Making the Climate: Rethinking the Role of Science in Global Climate Politics," Professor Bentley Allan at Johns Hopkins Political Science department seminar, discussant, March

Workshops Organized

2015**:**	"The New Earth: The Politics of Planetary Places and Spaces," graduate workshop at Johns Hopkins University, co-organizer, April
2013-2014:	Political Science Graduate Student Colloquium, co-organizer

PROFESSIONAL AFFILIATIONS:

Member, Phi Kappa Phi (since 2008)
Member, International Studies Association (since 2011)
Member, American Political Science Association (since 2011)

PROFESSIONAL DEVELOPMENT:

Workshops

2016:	International Studies Association Northeast Pedagogy Workshop, November
2016:	Johns Hopkins Teaching Institute, May
2016:	International Studies Association Career Course, "Simulations and Games," March
2015:	Institute for Qualitative Multi-Method Research, Syracuse University, June
2014:	European Consortium on Political Research, Winter School in Methods, February

Reviewing

2016: Referee, International Studies Association Compendium, “International Regulation of Ocean Pollution and Ocean Fisheries,” July

SERVICE:

Women’s Debate Institute

Since 2012: Member, Board of Directors
Lecturer, Summer Institute

Current: Member, Executive Committee
Member, Instructional Programming Committee
Member, Finance and Development Committee